THE EAST AFRICAN AGRICULTURAL JOURNAL

Issued under the Authority of the East African Governors' Conference and published every other month
JANUARY, MARCH, MAY, JULY, SEPTEMBER, NOVEMBER

Editor:
Director, East African Agricultural Research Station, Amani.
Editorial Board:
Directors of Agriculture, Kenya, Tanganyika, Uganda, and Zanzibar.
Assistant Editors:
R. E. Moreau, Amani; J. B. Gould, Department of Agriculture, Nairobi.

Subscription 5/- per annum, or 1/- per copy, post free, payable through any Agricultural Officer, or to the Government Printer, P.O. Box 128, Nairobi, to whom all business communications should be addressed. (Subscribers are advised to remit postal orders in payment, otherwise bank commission must be added in the case of cheques.) Editorial correspondence should be addressed to the Editor, Amani, via Tanga, Tanganyika Territory.

Matter submitted for publication should preferably be sent through the local member of the Editorial Board. Manuscripts should conform with the recommendations contained in *Notes for Authors*, which may be obtained from the Government Printer, Nairobi, or from a member of the Editorial Board.

Twenty-five separates of original articles will be sent free to authors. Additional copies can be supplied on payment if application is made at the time the manuscript is submitted.

Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to Amani.

A Colombian Coffee Manual

Colombia has long had a reputation for producing a high grade coffee, and in 1928 growers, brokers and exporters formed a Federation to protect and promote the interests of the industry and to initiate experimental work. One of the first activities of the Federation was to undertake the preparation of the Colombian Coffee Planters' Manual, published in 1932, and not so far issued in a new edition. Although the export of Colombian coffee on a big scale is a fairly recent development Colombian growers have had more than a century of experience behind them; the quality of their product is high; yet at the time the Manual was issued practically no local scientific work had been done on the crop. As a consequence the manual is an exposition of coffee-growing from an empirical and traditional viewpoint.

In the circumstances it is not surprising that the authors of the Manual find little of value to them in foreign literature. In East Africa, however, the cultivation of coffee (*C. arabica*) is comparatively recent. It has extended rapidly on a plantation scale as opposed to a peasant industry, subsequently bringing to the fore many problems of management and husbandry for investigation. In the solution of many of these the experience of planters in other parts of the world may

be a valuable guide. The Manual is printed only in Spanish, and it has fortunately been possible to arrange for an English abstract, which appears in this number, to be made by an East African coffee planter, Commander H. V. Low. Comments from the Uganda point of view have been contributed by Mr. A. S. Thomas as an appendix to the abstract. There is much in this Manual that is of interest to East African coffee planters, but it should be borne in mind that the natural conditions in Colombia are in general more favourable for coffee growing than those in many parts of Africa; the rainfall is more regular and there is a remarkable lack of serious pests and diseases,[1] possibly because conditions are more favourable or possibly because the widely dispersed small holdings do not provide centres of infection.

Climatic conditions considered suitable for coffee growing are defined and do not differ greatly from those specified for Kenya.[2] The soils are clayey, of volcanic origin, and carrying a forest cover. Soil exhaustion has not apparently occurred to any serious extent, but the authors remark that the time is at hand when some manuring will be necessary. The use of green manures, compost of coffee pulp, and stable manure supplemented by artificials are under investigation.

The need for very careful preparation of the land before planting is stressed and selection of seed from the best trees advocated, avoiding the planting of peaberry, as it is stated that plants raised from peaberry are likely to produce only peaberry. It is unlikely that this theory is correct, as a peaberry from an otherwise normal Arabica tree will have a similar genetical constitution to a normal bean and produce a similar plant. Peaberry may in fact give a more vigorous seedling, as it has a bigger food reserve proportionately than a normal bean.

Planting seed in boxes of sand, it is claimed, accelerates germination, but it appears that the young plants, very closely spaced (10,000 seeds to the square metre), are left in these boxes until they have four or five pairs of leaves. In East African sand, plants thus treated would be very yellow on transplantation to the nursery beds, and much attenuated. Ball planting from nursery to field is assisted if the beds contain a proportion of clay.

The function of, and necessity for retaining, the taproot of Arabica coffee is a controversial subject in Colombia as well as in East Africa.

Discussing the problem of shade in coffee culture, the authors conclude that shade and quality go hand in hand. Their list of disadvantages of no shade indicate that over-bearing and biennial bearing are features that can be overcome by judicious use of shade in Colombia. A mixture of species is advocated, and also the selection of indigenous forms suitable for each district. Where possible, established trees should be retained when clearing new areas of land. Quite recently investigations on the value of indigenous East African trees for use as shade have been started, but the idea of mixing species has not been advocated. As much attention must be paid to the cultivation and pruning of the shade trees as to the coffee.

A system of pruning coffee is simply and clearly set out. The production of umbrella-shaped trees by wrong methods or neglect of pruning is to be avoided, as all the lower primaries are lost and the

[1] Ukers, W. H.: *All About Coffee*, 2nd Edition, 1935; New York; p. 163.

[2] *Coffee in Kenya*: Government Printer, Nairobi.

bearing surface consequently reduced. This may be a disadvantage in Arabica coffee, but Robusta, some forms at least, lend themselves to this method of cultivation. Once they (Robusta) have made a good umbrella cover they are virtually self-pruning and maintain a high level of production.

It has not yet been definitely established in East Africa that quality of the bean is influenced by the type of wood on which the crop has been borne. In this Manual it is stated definitely, but on what evidence we do not know, that "succeeding crops will be borne on the outer end of the branch, and each crop will be approximately half the quantity, quality and size of the previous one."

The literature on coffee-growing contains many references to methods of regenerating old and unprofitable plantations; usually stumping is recommended. But, as pointed out in this Manual, it cannot be expected that a vigorous tree can be obtained from a poor, weakly plant on exhausted soil. If a tree has suffered from over-cropping and dieback at any stage in its life-history it has probably suffered some permanent injury that precludes the possibility of its ever becoming a profitable unit.

The Manual indicates that sound agricultural practice and almost maternal care of the coffee bush in a suitable environment are conducive to a long and profitable life and a high quality product, an observation which must be obvious to all. Colombian planters must be envied by the harassed East African coffee planters.

L. R. D.

Manual del Cafetero Colombiano—The Colombian Coffee Planters' Manual

In view of the important position of Colombia as a producer of mild coffee, this coffee planters' handbook, published (in Spanish) in June, 1932, by the National Federation of Coffee Planters of Colombia, in conjunction with the technical staff of the Agricultural Experimental College of La Esperanza, is of considerable interest. Emphasis is laid on local conditions and cultural methods and the authors state that foreign literature on coffee is of little significant value to them. Technical terms are avoided as much at possible so that the book can be understood by even the least intelligent peasant cultivator. In the sections dealing with diseases, pests, etc., scientific names and descriptions are put side by side with the local names, as the latter vary in different parts of the country. The whole book is well illustrated with simple diagrams and photographs, and its object is described as being to awaken the planter's interest and make him so enamoured of his vocation that he will feel that his toil is repaid as much by the satisfaction of work well done as by material gain.

Suitable climates for coffee growing are discussed briefly. Altitudes from 3,000 ft. to 6,000 ft. on slopes facing east and with well distributed annual rainfalls of from 45 to 60 inches are considered to be the most favourable conditions in Colombia. It is thought that a mean temperature higher than 70° F., combined with excessive humidity, shortens the life of Arabica coffee and causes the bean to be of inferior quality.

The anatomy of the coffee tree is explained in great detail and a number of simple diagrams are given. The statement is made that a plant raised from a "peaberry" is likely to produce only peaberry coffee.[1] The characteristics of some of the better known economic varieties of coffee are explained; under the description of *Coffea Laurentii* Laurent—the Robusta coffee of Java—is expressed the hope that this variety, which is stated to be especially resistant to *Hemileia vastatrix,* should be propagated in Colombia in case this dread disease should ever be introduced to ravage the country.

The composition of the soil in various parts of the country is given for the experts, with apologies to the small holder, to whom it is not expected to be of much interest. An amusing insight into the local sanitary customs is given by the special injunction to intending planters not to judge the quality of the soil by the fine, healthy appearance of trees situated near habitations, as these will have been well manured by refuse thrown out from the houses! When preparing new ground for plantations, removal of forest stumps by dynamite is recommended, both on account of its economy and for the beneficial effects of the explosions on the subsoil, especially on the markedly clayey soils of the Colombian coffee districts. It is recommended that holes should be dug at least six months before being used for planting. Stress is laid on the fact that a coffee tree, once planted, should live a useful life of at least forty years, for which reason it is worth spending some

[1] The Chief Scientific Officer, Coffee Research and Experimental Station, Lyamungu, notes: "The percentage of peaberry cannot be entirely due to a genetic cause, as without exception the application of sulphate of ammonia after the long rains in a series of experiments resulted, in *wet* years, in an appreciable reduction, thus pointing to a lack of nitrogen at a critical time as being an important factor."

time and trouble in preparing the site in which it is to live. All indigenous trees suitable for shade, which may be found growing on the site of the new plantation, should be left. Contour planting is recommended, and the spacing between plants should be triangular. About 8 ft. distance between plants is the current practice in the country, but the authors suggest that 10 ft. is likely to prove better for Arabica coffee, and a considerably greater distance for Marogogipe and other varieties.

Planting is all done from seed, efforts to propagate by cuttings or grafting having proved unsuccessful. Planters are advised to select seed from their best trees and the practice of employing self-sown seedlings is strongly deprecated as only the seed of weak or sickly parents would fall on the ground before being harvested. Seed should be taken from the second or later crops of primaries or secondaries, but never from tertiaries. After pulping, washing and drying the seed, it should be soaked for five minutes in a one-tenth per cent solution of copper sulphate to remove fungus, and then quickly washed in clean water. The soil of seed germination beds should also be well watered with a one-tenth per cent solution of cyanide of potassium, though no reason is given for this. The most economical method of germinating seeds is to place them in a shallow box half filled with sand and cover them with a further layer of sand two centimetres thick; it is stated that in this way seed will germinate in 20 days as against 25 to 30 days if planted in beds. Ten thousand seeds can be accommodated in a box one metre square. The nursery beds, into which the germinated seedlings are put when they have four or five pairs of leaves, should have a certain proportion of clay in the soil in order to facilitate the removal of earth round the roots of the plants when they are transplanted to their final position. Weed growth in nursery beds may be discouraged by covering the soil between the plants with a layer of sand about 2 cm. thick.

The authors note that the general custom in the country is to cut back the tap roots of the plants on transplanting, but are opposed to the practice as "nature never makes mistakes," so that the tap root must serve some useful purpose, though they state that it does not absorb nutriment and its only known use is to anchor the plant in position. Planting should always be done at the beginning of the rainy season, and plants must be planted in *pilones,* i.e. with balls of earth round their roots. In spite of the utmost care, some roots are invariably broken in transplanting, and so the equilibrium between roots and branches must be balanced by cutting off the two lower primaries.

Considerable space is devoted to a description of the worst types of weeds found in the coffee plantations. Two weedings a year, in the dry season, are recommended in established plantations, and, in addition, young areas should be "ring-weeded" twice. Special stress is laid on the advantage of placing the weeds in contour ridges and of weeding by hand the area close to the trunk of the tree in order to avoid damaging the surface roots.

An interesting chapter is devoted to the question of shade trees in coffee plantations. Coffee planters in the Old World are blamed for lack of care in the selection of trees for shade, with consequent deterioration of the coffee and disparagement of the use of shade. Planters in Central America were the first to use shade with discrimination and commonsense, and the almost universal custom of employing Leguminosae was later justified by the discovery of their nitrogen-fixing qualities. Brazil, it is noted, em-

ploys no shade in her coffee plantations and the industry is becoming convinced this this is one reason for the poor quality of its coffee. The disadvantages of growing coffee without shade are given as follows:—

(1) Excessive development of wood and a tendency towards upward growth.
(2) Small leaves and lack of chlorophyll.
(3) Irregular flowering resulting in irregular crops.
(4) The bean is smaller, lighter and more acid.
(5) Predilection to disease.
(6) Short-lived trees.

The effect of shade is to keep plantations cool, to limit the free circulation of air thus regulating the moisture content, and to keep the soil humid. A fundamental factor in the production of good quality "mild" coffee is shade. Coffee grown in Colombia without shade flowers at short, irregular intervals all through the year and the trees are very short-lived. Shade also increases the growth of primaries and secondaries, thus increasing the productive capacity of the tree. Deep-rooted shade trees render the nutritive substances of the subsoil available to the coffee trees by returning them to the surface of the soil in the form of humus caused by leaf fall. Weeding is reduced as many weeds cannot exist under shade. The spacing for shade trees should be from 20 to 30 ft., according to the types of trees used. In choosing trees for shade, the following points should be borne in mind: They should be of rapid growth and long-lived, with branches which spread well at a convenient height; they should be fairly deep-rooted, so that their roots do not occupy the same layer of soil as those of the coffee trees; their sap should be disagreeable or poisonous to insect pests; they should not grow thorns which may injure the workers; they should give good timber for building, and fruit which can be used for fattening domestic animals; and finally their leaves and other residues should form good humus. One point in the selection of trees for shade to which far too little importance has been given is the use of a mixture of species, using all those most appropriate to each district. The reason for this is that no single species is known which unites in itself all the needful qualities, and that, when only one species is used, many trees die from no apparent cause. Most of the trees employed are indigenous, and under natural conditions they live surrounded by many other species, each of which has its different needs and throws off different substances which may be useful to one but useless or even injurious to another. Temporary shade is recommended until the permanent shade trees are fully grown, and for this purpose bananas or even maize may be employed; bananas are especially useful as they keep the soil humid. As permanent shade, no less than seven varieties of Inga are mentioned. *Grevillea robusta* comes at the end of the list, but the authors note that this tree, so widely employed as coffee shade by planters in Africa, is very inferior to the others mentioned and has the great disadvantage that its fallen leaves smother the foliage of the coffee trees and do not rot easily. Young shade trees must be cultivated frequently and pruned regularly as they grow up so as to train the branches to form good cover.

A short chapter is devoted to cash crops and other auxiliary sources of income. Beans of non-climbing habits may be planted, and apiculture is especially recommended.

Little manuring has been done in Colombian coffee plantations so far, and too many planters treat their soils as

mines from which they extract a product named coffee by means of a machine called a coffee tree. The time is at hand when manuring will have to be employed and the various effects of the three main artificial fertilizing agents — nitrogen, phosphoric acid and potash—are briefly explained. Some formulæ for "complete" fertilizers are given, those already on the market and recommended for Colombian soils being two "Nitrophoska" formulæ of 16-16-20 and 15-11-26, and one called "Americus" with a formula of 9-12-20. The staff of the Agricultural College is studying the effects of these and other "complete" fertilizers and will publish their results in due course. But chemical fertilizers should only be employed when falling production shows the need of them, and the coffee soils of Colombia are very far from having exhausted the supplies of natural manures. Stable manure is available in large quantities, but care is needed in its preparation; it must be kept damp but protected from rain, while the application to it of lime, favoured by some planters, is deprecated as it causes loss of nitrogen in the form of ammonia. A manure heap carefully prepared will mature in from five to six months, and is ready for application to the fields, but as the average manure formed from cattle and horse dung has the formula 5-1-6, it is short of phosphoric acid, which may be added at the time of application to the plantation. Another economical source of manure is coffee pulp, if correctly prepared. But in order to encourage rapid fermentation and decomposition, provision must be made for a free circulation of air throughout the mass of pulp, and two diagrams are given which show alternative means of achieving this end, by means of which the pulp will mature in about two months instead of the one to one and half years taken if the customary methods are employed. Another advantage is that the bad odours usually caused by the fermentation of the pulp are avoided.

Owing to the broken nature of the country, manures have to be applied to the plantations by hand, and the most economical system of doing so is to bury them in shallow trenches dug between the rows of trees along the contours. All manures, especially chemicals, should be applied in the dry season, which is spring in Colombia, but before the soil has become too dry, and it should be done immediately after weeding and pruning have been completed. The results of experiments on Colombian soils show that for chemical fertilizers—Nitrophoska and Americus—from 250 to 350 grammes annually may be applied to each tree, and from five to ten kilos of stable or pulp manure. If lime is needed, from two to six kilos should be dug into the soil every four or five years, but planters are recommended to seek expert advice before doing so.

The planting of cover crops and green manures is another method of enriching the soil. Two examples are given to emphasize the dangers of erosion. In one case a fall of 68 mm. of rain, not uncommon in Colombia, caused a loss of 100,000 kilos of soil per hectare on slightly sloping land, while in another a sandy soil with a slope of four per cent lost a layer 17 cm. thick over a period of 23 years, a layer which it is estimated must have taken two thousand years to form.

Coffee is almost universally trained on the single-stem system in Colombia, and a good deal of space is devoted to a detailed explanation of the best procedure. The principal defect of the old method of pruning was the gradual disappearance of all primary branches during the first twenty years of the tree's

life, and the main object of the new system is to correct this fault. There are two kinds of pruning: the object of one is to form a perfect tree, while the other conserves the structure and encourages crop production. For formation pruning the tree should first be capped about one year after having been planted out, leaving four or five pairs of primaries, the lowest of which should be at least 50 cm. above the soil level. Capping should be done by cutting off the main stem one node above that of the top pair of primaries which are to be left, and at the same time cutting back the pair of unwanted primaries close to the stem. This first capping will have the following effects: thickening of the main stem and of the lower primaries, production of numerous secondaries and sucker shoots, and early crop of excellent quality. During the next ten months all suckers should be removed and, at the end of this period, the plant should again be capped one node lower than before, following the same procedure for this as previously. Only the best shoot of those which will grow from this new cut should be left, and after about one year this should again be capped, but this time leaving only three pairs of useful primaries. For the next ten months all shoots should be removed as before, and the same procedure followed up to and including a third capping at the end of the third or fourth year, but in this case the third and last capping should be made at the sixth or seventh primaries, so that the tree as finally formed should consist of from 13 to 15 pairs of primaries and its height about one and a half metres.

The correct shape of the tree must now be conserved by maintenance pruning. In order to do this intelligently, the following general observations must be thoroughly understood:—

(1) The first crop of any branch covers approximately three-quarters of the length of the branch, counting nodes from the trunk outwards.

(2) Succeeding crops will be borne on the outer end of the branch, and each crop will be approximately half the quantity, quality and size of the previous one.

(3) The coffee tree prefers to bear its fruit on wood of less than a year old.

(4) Every coffee tree needs a certain amount of matured wood in which to store reserves of nourishment, but any upsetting of the balance between new and old woods tends to cause the flower buds to change into vegetative buds.

Never cut off a primary branch as long as it is alive; it is irreplaceable. It may be shortened when necessary, but this should always be done by cutting across a node so as to leave one bud, and never by making a cut between two nodes. It is generally a good rule to thin out secondaries and tertiaries by cutting off alternate ones. After the first crop of a tertiary, cut off both it and the secondary from which it comes, as neither are likely to bear usefully again. All vertical shoots should be suppressed unless they are wanted for building up a broken tree structure. Never leave dried or dead branches on a tree. Stumping about ten centimetres above the ground level may be resorted to if it is desired to form a completely new tree from an existing root system, but failure is certain unless the stump is young, robust and healthy, and the soil in good heart.

The best time to prune is immediately after harvesting the crop. There is no scientific confirmation of the common belief that it is better to prune during a waning than a waxing moon.

Brief mention is made of the Guatemalan and Costa Rican systems of pruning, but the authors do not consider that they are in any way superior to that which they recommend for Colombian coffee plantations.

Two long chapters, with many illustrations and diagrams, some of which are coloured, are devoted to the pests and diseases of coffee. Some of them are not found in coffee plantations in the Old World, while others mentioned, for example, *Hemileia vastatrix,* have not yet been discovered in the American continent. The treatments and precautions recommended are much the same as those in use in other parts of the world.

Harvesting, pulping, hulling and grading are described and explained in detail, with diagrams of suggested installations of various capacities. Particular stress is laid on the necessity of correct grading in order to attract buyers in the foreign markets, and Government regulations prohibit the export of inferior qualities.

The book closes with a short chapter on personal hygiene and sanitation, with a few hints on first aid in case of accidents.

This handbook is full of good advice to the coffee planter. It is based on sound ideas worked out on economical lines to suit the small planter as well as plantations owned by large syndicates. Nothing very new or startling is contained within its pages, but the results of the Federation's own recent research are pleasantly intermingled with traditional methods; some proved to be useful by experience and others handed down from father to son with very little known justification for their adoption. Conditions in many parts of the country are evidently very primitive, and the book is intended to arouse the interest of the peasant cultivator.

The reader is introduced to intensive methods of cultivation, as understood in East Africa, though at present there does not seem to be any urgent need of their adoption as the soils are still generally rich enough in accumulated reserves to supply the normal requirements of the coffee plantations. In this respect the position is similar to that on the Pacific coast of Guatemala, where the application of chemical fertilizers is at present almost unknown, whereas planters in the neighbouring republic of San Salvador apply them in large quantities to their now impoverished soils.

In comparison with the ignorance and lack of system in the use of shade prevalent in East Africa, the views expressed in the book are very instructive, and especially so is the stress laid on the advantage of employing mixed varieties of shade trees. The opinion quoted, that the poor quality of Brazilian coffee is partly due to the absence of shade, is illuminating.

It is a very sound book, written in an interesting manner, and should prove of great benefit to those for whom it is intended.

H. V. L.

APPENDIX

The whole book seems very practical, and to be quite one of the best ever written on the cultivation of coffee. The climatic requirements of the crop are well summarized; the suggestion that a relatively high humidity and a mean temperature above 70° F. will cause Arabica coffee to be short-lived is in accordance with experience in Uganda; while the plants may show much promise for a few years after planting in the warmer, moister parts of the country, yet few trees have a useful life of forty years, as in Colombia. Robusta coffee—which should be called *Coffea canephora,* a name prior

to *C. Laurentii*—is more suited to tropical conditions than is Arabica coffee; on that account, rather than to an innate resistance to the disease, it is less liable to be badly affected by *Hemeleia vastatrix*.

As in Colombia, so in Uganda, the coffee near houses usually is much more vigorous than that at a distance from them; in fact, the value of household refuse as a dressing for coffee is a most important factor in the cultivation of coffee by Africans, as may be seen from the fine old Robusta coffee trees growing near house sites. When land in Colombia is cleared from forest and carefully prepared, the coffee must grow very well, or else the Manual would not recommend a spacing of ten feet for Arabica coffee pruned on the single-stem system; if there were no overhead shade, so wide a spacing would be disastrous owing to soil exposure. The methods of sowing seed, of raising seedlings and of planting them in the field are very careful, but it appears that unnecessary emphasis is placed on the value of the taproots; in wild Robusta coffee, at any rate, the seeds germinate under forest conditions, there being a thin layer of mould over hard soil, with the result that the taproots of wild seedlings are relatively small and twisted and that, early in the life of the plants, there is a good development of lateral roots. The idea of removing by hand all the weeds growing close to the trunk of the trees is very sound, for it is a great mistake to disturb the dense mat of roots that grow there near the surface.

The sections on the value of shade for coffee and on the methods to provide it are excellent, especially with regard to the ideas of retaining any suitable trees when forest land is cleared and of planting a mixture of shade trees; the only controversial point is the statement that unshaded coffee makes excessive wood. In Uganda one great advantage of shade is that it increases vegetative growth and renders the coffee less liable to severe setbacks through over-bearing. But it does not follow that the trees useful for shade in Central America will be of value in Uganda; for example, a species of *Lonchocarpus* which is extensively planted as a shade tree in Costa Rica has made such slow growth at Entebbe as to be of little value. The mention of the use of bananas to provide temporary shade is interesting, for it is in accordance with the system of coffee cultivation indigenous to Uganda.

It is surprising that, when coffee prices are so low, pruning on such elaborate and careful lines can be carried out, but it must be owned that the section on pruning gives a most reasoned exposition of the single-stem system. The warning against stumping trees when they are not vigorous is well put; it is inadvisable to cut down a tree, either of Arabica or Robusta coffee, unless some suckers are already growing; if only old wood is left the tree may produce a new framework but it will seldom recover its former strength, for stumping must give a great check to the root system.

In addition to the emphasis on shade, the advice on manuring coffee is of the utmost importance; all too frequently coffee planting is regarded as a method of "mining" the soil. It is evident in parts of Uganda, at any rate, that if Arabica coffee is to be a permanent crop, it must be manured; it is obvious that soil factors are important or else why should coffee deteriorate so rapidly after a few years, even under relatively cool conditions? It would be most interesting if analyses of the Guatemala soils, which require no manures, could be given in comparison with those of soils which do need them.

A. S. T.

Natural Reversion to Grass

OBSERVATIONS ON THE EFFECT UPON SOIL FERTILITY OF (a) ESTABLISHED GRASS AND (b) CLOVER AS COMPARED WITH NATURAL REVERSION TO GRASS

By D. C. EDWARDS, *B.Sc., Agricultural Officer in Charge Grassland Improvement, Department of Agriculture, Kenya Colony*

The natural reversion of areas in which soil fertility has been depleted is a matter which has received much consideration recently in connexion with both the reconditioning of extensive eroded areas and the recovery of lands which have been partially exhausted by continuous cropping with maize [1]. No exact information has been available as to the effect of natural reversion upon fertility and the question arises whether, where this course is practicable, it would be of advantage to establish a pasture artificially by sowing or planting. The following observations cast some light upon this question.

At Kabete, under an average annual rainfall of 40 inches per annum, and on Kikuyu red loam soil, an experiment consisting of randomized plots (each 11 ft. by 7 ft.) was undertaken with the object of comparing six ecotypes of *Chloris gayana* (Rhodes grass). The sowing was carried out in the recent November rains, and the area was carefully selected for the experiment with a view to soil uniformity, but it was necessary to utilize land which had been subjected to three different treatments. These were as follows: In area (*a*) the local indigenous clover, *Trifolium Johnstonii*, had been established since November, 1935; in (*b*) natural reversion had been permitted since May, 1935; and in (*c*) Rhodes grass and Kikuyu grass had been established since May, 1935. A number of the randomized plots fell into each of these areas.

All three areas were ploughed and cleaned in March, 1934. Before this date they formed part of a grazing paddock dominated by natural Kikuyu grass. Preceding the establishment of *Trifolium Johnstonii* in strip (*a*) and natural reversion in strip (*b*), British grasses were sown in May, 1934, and again in May, 1935. These species died in the seedling stage, owing to their being unsuited to the climatic conditions. Area (*c*), subsequently planted to Kikuyu and Rhodes grass, was allowed to remain fallow until the grasses were established in May, 1935. During this period, before the commencement of the differential treatment under discussion, all three areas were kept thoroughly clean, and were, to all intents and purposes, bare ground for approximately a year. These facts are mentioned as they indicate that the present investigation deals with ground that may be regarded as completely denuded of vegetation at the outset.

Following the germination of the six Rhodes grass ecotypes, a dry period set in and there were considerable casualties amongst the seedlings. This effect was clearly different in the three areas with differing pre-treatments. Further, the development of the remaining seedlings was markedly different eight weeks from sowing. The greatest development had taken place on the clover area, where many of the creeping stems of the grass were three to four inches long; on the area previously under grass, the plants were considerably

smaller and in a number of the plots had not commenced to develop runners; while the natural reversion area appeared as a practically bare strip between the other two areas.

The survival of seedlings in a period of deficient rainfall is closely connected with the rate at which the young plants are able to develop, and this appears obviously to be determined by soil fertility. The survival of the seedlings in this instance may therefore be taken as a basis upon which to compare the fertility resulting from the different pre-treatments in the three areas under discussion.

Counts of seedlings on the plots which fell within the areas, two months after sowing the six ecotypes of Rhodes grass, gave the following results. A six-inch quadrat was used and ten readings were made on each plot. As may be expected, the germination capacity and the rapidity of development of the seedlings differs from one ecotype to another.

These results show that there is a marked lack of fertility in the area which has been subjected to natural reversion as compared with the other two areas. The figures are clearly supported by the appearance of the plots, as may be seen from the photograph which shows the junction between the area previously under clover and that previously allowed to revert naturally. Remaining portions of the clover and natural reversion strips are seen in the foreground. It will be observed that the old boundary of the clover plot is clearly visible cutting through a line of ecotype plots. The area previously under grass is to the right and not seen in the picture.

Showing survival and development of *Chloris gayana* seedlings in clover area as compared with natural reversion area, 8 weeks after sowing.

AVERAGE NUMBER OF SEEDLINGS SURVIVING PER SIX-INCH QUADRAT

Ecotype	(a) Clover Area	(b) Natural Reversion Area	(c) Grass Area	Stage of Development		
				(a) Clover	(b) Natural Reversion	(c) Grass
Kabete, Kenya	0·9	0·01	0·8 and 1·1	Runners 3″ to 4″ long	Plants extremely small.	Plants small.
Queensland, Australia	4·5	0·1 and 0·4	1·5 and 1·0	Runners 3″ long	Plants extremely small	Proportion of plants well developed
Trans Nzoia, Kenya	1·9	0·1	5·0 and 3·7	Runners 2″ to 3″ long	Plants very small	In general plants small
Alego, Kenya	4·7	0·2	3·8 and 0·7	Runners 4″ to 6″ long	Plants very small	Plants medium to small
Teso, Uganda	0·4	Nil and Nil	0·2 and 0·5	Runners 2″ to 3″ long	Bare plots	Few plants well developed
Kafue, Rhodesia	0·5 and 0·3	Nil	0·2 and 0·2	Well developed	Practically bare plot	Very few plants, but fairly well developed
Average of all Ecotypes..	1·9	0·1	1·6			

NOTE.—One plot of the Trans Nzoia ecotype which gave a seedling count of 13·9 in the clover area has been omitted from the Table, as the result was considered to be due to localized soil fertility from an unknown cause.

A survey of the remaining portion of the natural reversion strip (78 ft. by 21 ft.), carried out in January, 1939, showed the herbage to be constituted as under:—

Species Present in Area Allowed to Revert for 3½ Years

Commelina spp. (2).—Very frequent.

Setaria verticillata.—Very frequent (in better two-thirds of plot only).

Conyza Schimperi.—Frequent.

Galinsoga parviflora.—Frequent.

Diplotaxis sp.—Frequent.

Portulaca spp. (2).—Frequent.

Sonchus oleraceus.—Occasional.

Digitaria abyssinica.—Occasional.

Chloris pycnothrix.—Occasional.

Oxygonum atriplicifolium. — Occasional.

Ipomoea batatas. — Occasional, in limited area only.

Dactyloctenium ægyptium.—Rare.

Eleusine multiflora.—Rare.

Solanum nodiflorum.—Rare.

Trifolium Johnstonii.—Rare.

Cyperus rotundus.—Rare.

Oxalis sp.—Rare (one small colony).

Crotalaria incana.—Two plants encountered.

Cynodon plectostachyum.—Two plants encountered.

Bidens pilosa.—Two plants encountered.

Eragrostis tenuifolia.—Single plant encountered.

Cynodon dactylon.—Single plant (escape from nearby plots).

Digitaria horizontalis.—Single plant encountered.

There is a fertility trend, showing reduced fertility in the portion of the strip away from the Rhodes grass experiment on which the above seedling counts were made. In the two-thirds of the strip nearest to the experiment the herbage cover is approximately 30 per cent, while in the remaining one-third it varies from 10 per cent to 15 per cent. The proportion of grasses in this cover is about 50 per cent in the better two-thirds and negligible in the remaining one-third.

Discussion

This investigation appears to lead to the following conclusions: (*a*) that soil fertility is influenced more favourably by the artificial establishment of grasses and legumes than by natural reversion; (*b*) that natural reversion is extremely slow under the climatic conditions of Kabete. Although there is no evidence of soil erosion, observations further tend to show that fertility may have been actually reduced during the early stages of reversion, since Kikuyu grass, which is natural to the area, and which has appeared spontaneously in nearby plots under grass but demands high fertility, has failed to make its appearance in the natural reversion area. This fact lends support to the view that organic matter is reduced in soils exposed to the sun.

It may be assumed that the introduction of the grazing animal would have a decided effect in hastening reversion of an area to grass, by means of the seeds introduced in the manure and by the addition of organic nitrogen, but it will be seen that the area under observation affords, after a considerable period, herbage of very light carrying capacity, and it is difficult to escape the conclusion that the artificial establishment of a pasture, on which animals could be rapidly concentrated, would be amply repaid, at all events where the amount of land available is a consideration. It is also evident that, since this result has been obtained under a comparatively high rainfall (40 inches per annum), natural reversion to grass can be expected to be even slower with the lower and more erratic rainfalls which obtain over the greater part of the country.

In the list of species important in the natural reversion area, apart from the annual grasses, it is probable that a number are of value for grazing. *Commelina*, which forms a considerable proportion of the herbage, is known to be palatable and is used by natives locally for feeding to sheep and goats [2].

Regarded from the point of view of attempts to recondition extensive native pastoral areas where large-scale sowing or planting of grass is likely to be out of the question, these observations suggest that, in view of the extreme slowness of recovery to be expected from natural reversion alone, it should be the aim rather to introduce the grazing animal to protected areas seasonally than to rely upon complete protection from grazing over protracted periods.

The bearing of the observations on the use of cover crops in plantations, such as coffee, in preference to dependence upon the production of a natural cover of weeds, is obvious, as is also the bearing upon the native practice of fallowing land in shifting cultivation.

Finally, it may be noted that although the advantage which may be expected from the effect of the clover over the grass is not clearly shown, at the present stage, in the numbers of Rhodes grass seedlings which have survived following these two crops, the increased fertility due to the clover is clearly evident in the greater development of the surviving seedlings.

The foregoing observations are presented, not as providing conclusive evidence upon this important question of the effect of gradual reversion to natural vegetation upon soil fertility, but rather to suggest directions in which further study is desirable.

References

[1] Ball, R. S.: "Mixed Farming in East Africa, I," *E. A. Agric. Journal*, Vol. I, No. 5, p. 399, March, 1936.

[2] Edwards, D. C.: "Sierra Leone Grasses," *Tropical Agriculture*, Vol. 6, No. 5, p. 141, May, 1929.

The Utilization of Sisal Waste in Java and Sumatra—Part IV

By J. E. A. DEN DOOP, *Bandoeng, Java*

After the findings, as described in Part III of this article, the author designed in 1928 a field experiment, S.93, in the old red-soil area with a view to finding out the effect of green manure (*Tephrosia candida* D.C.), with and without various combinations of artificial manures, on sisal yield. The green manure was planted in 1928, worked into the soil in various ways in 1929, and the sisal was planted thereafter, at the end of the latter year. This experiment, S.93, has been reported upon from the point of view of green manuring in a Dutch journal.[1] Some of the yield data, as relevant to the present subject, are to be found in Table I, together with some other data.

It will be noticed in Table I that fibre yield without any manure is very small in S.93, viz. 5.54 tons per hectare, whereas with potassium but without any further manure such yield is about three and a half times as high, viz. 19.10 tons per hectare, which is quite a good one for practical purposes. It is thus proved with certainty that the old red soil is very exhausted as regards potassium, whereas exhaustion as regards phosphorus and nitrogen is at least very much less.

To further understand the exhaustion stage of phosphorus and nitrogen in the old red soil, the three first yield rows of Table I should be compared with each other. The first row shows fibre yield with full manure to be 22.94 tons per hectare. The second row shows that the elimination of phosphorus from the full manure results in only a small drop from 22.94 to 21.18 tons of fibre per hectare. This difference would have been even smaller had cutting for the non-phosphorus treatment been continued until the 92 per cent poling stage, as in the full-manure treatment. It can thus be inferred that the old red soil, although very exhausted as regards potassium, still contains a considerable amount of phosphorus.

The third row of Table I shows the yield for the non-nitrogen treatment. This yield is a little lower than same for the non-phosphorus treatment, viz. 20.65 as against 21.18 tons of fibre per hectare. However, cutting stopped for the non-nitrogen treatment at the 58 per cent poling stage, whereas for the non-phosphorus treatment it stopped at 75 per cent. Had cutting for both treatments stopped at an equal stage, say at 92 per cent poling as for the full-manure treatment, fibre yield for the non-nitrogen treatment would probably have been a little higher than for the non-phosphorus treatment. Thus it may be inferred that the old red soil, although very exhausted as regards potassium, still contains a considerable amount of phosphorus and also a probably even larger amount of nitrogen.

As, however, by more potassium the yield in S.93 might have been raised and in varying degrees according to different treatments, said amounts of phosphorus and/or nitrogen cannot be expressed in terms of sisal-fibre yield, whereas this can be done for potassium in the old red soil, as it was in 1929, viz. about 5.5 tons of fibre per hectare.

[1] "Groene Bemesting, Kunstmest en andere Factoren in Sisal—en Cassava-Productie," *De Bergcultures*, 1936, No. 42, pp. 1306-1327.

TABLE I

SOME SISAL YIELD DATA (IN TONS OF FIBRE PER HA.) FROM EXPERIMENTS S.93, S.485 AND S.554

In S.93 the manure amounts mentioned do not include those applied less than one year before the experiment ended and only half the amount applied 14 months before that date.

Treatments							Time After Planting, Expressed in Months												Poling percentage at last cut
Green Manure	Artificial Manure in kg. per ha. N	P_2O_5	K_2O	MgO	CaO		16	22	29	36	43	48	55	62	68	74	80	82	
Tops only ..	352	319	1,039	425	3,207	Fibre yield	0·78	1·57	3·48	6·05	8·76	11·84	14·72	17·93	19·97	21·82	22·32	22·94	% 92
Tops only ..	352	—	1,039	425	3,207	,, ,,	0·56	1·40	3·07	5·03	7·46	9·68	12·76	15·37	17·31	19·33	20·21	21·18	75
Roots only ..	—	319	1,039	425	3,207	,, ,,	0·45	1·02	1·98	3·58	5·86	8·55	11·47	13·49	15·94	17·93	18·94	20·65	58
None	—	—	1,039	—	—	,, ,,	0·60	1·36	2·57	4·31	6·37	8·46	10·97	13·23	15·21	17·07	17·96	19·10	69
None	—	—	—	—	—	,, ,,	0·53	1·19	1·89	2·49	2·96	3·45	3·84	4·35	4·74	5·10	5·29	5·54	(No poling)
S.554 Planted in March, 1933, on unmanured plots of S.68, i.e., in old red soil, extremely exhausted by a sisal crop as regards potassium. S.554 was manured with 210 kg. K_2O per ha., once every half year, beginning soon after planting.							Time After Planting, Expressed in Months												
							18	24	31	37	43	51	57	65					
						Fibre yield	0·11	0·30	0·60	1·22	1·93	3·28	5·41	8·11					(Not yet poling)
S.485 Planted in 1931 in fresh red soil after forest clearing, withou manure.							Time After Planting, Expressed in Months												
							15	21	27	32	38	45	50	57	64	70			
						Fibre yield	0·49	1·81	3·93	6·18	8·94	13·29	16·67	23·99	30·24	32·34			93

It need not be emphasized in speaking of potassium, phosphorus and nitrogen that these food substances have been considered only in so far as they were in a physiologically active state at time of absorption.

In March, 1933, when the sisal in S.93 of Table I was only four years old, a small sisal field experiment, S.554, was laid out on a part of the field experiment S.68 (compare Figs. 3 to 5 in Part III of this article), which had been planted in 1925 and ended in 1932. The special part of the latter experiment selected for S.554 was a small patch where the sisal of S.68 had received no manure and had soon become badly leaf-foot-diseased. The plots of S.554, receiving no manure, became very soon very badly diseased. Their yield being very low need not further be considered. The other plots were manured with potassium only, the sulphate and chloride forms being used in different plots. The first potassium dose was applied soon after planting and further applications were made once every half year. The applications were at the rate of 210 kg. K_2O per hectare. They were much heavier than in S.93 and they were begun at a stage of the sisal cycle about a year and a half earlier than in S.93.

The fibre yields of the manured plots of S.554 are to be seen in Table I. Fig. 1 gives a view of the experiment at an age of five and three-quarter years after planting.

To find the characteristics of these yields they are best expressed in terms of yield rate, i.e. of yield increase per unit time, say per month per hectare. The yield rates per month per hectare for S.554, together with same for the sole-potassium treatment of S.93, are to be found in Table II. It has been assumed

FIG. 1

S. 554 at an age of $5\frac{3}{4}$ years after planting. The sisal in the background has been manured with potassium only

The sisal church-yard in the front has not been manured

in Table II that cutting times, i.e. times between planting and cutting, coincided in S.554 and S.93. Table I verifies that this assumption is approximately correct.

TABLE II

YIELD RATES PER MONTH IN MANURED PARTS OF S.554 AND IN THE SOLE-POTASSIUM TREATMENT OF S. 93, EXPRESSED IN TONS OF FIBRE PER HA.

	Cuts.. ..	1st	2nd	3rd	4th	5th	6th	7th
Sole-potassium Treatment of S.93	Yield Rates..	0·125	0·164	0·249	0·294	0·418	0·359	0·323
Manured Parts of S.554 (only Potassium)	" "	0·032	0·043	0·089	0·101	0·270	0·355	0·339
Latter Yield Rates as Percentages of Simultaneous Former Yield Rates		26%	26%	36%	34%	65%	99%	105%

Table II shows that yield rate in the manured parts of S.554 is very low until the fifth cut inclusive, viz. until three and a half years after planting, i.e. during three and a half years of heavy potassium manuring. From then on it increases fast, and reaches in one year its maximum of 0.355 tons of fibre per month per hectare. This value is 85 per cent of the corresponding maximum for the sole-potassium treatment of S.93, which is 0.418 tons of fibre per month per hectare, as may be seen from Table II. The total fibre yield per cycle of the manured parts of S.554 may thus be estimated at 85 per cent of same for the sole-potassium treatment of S.93, i.e. at about 16 tons per hectare on the basis of cutting out at the 68 per cent poling stage. The author estimates that continuation until the 93 per cent poling stage would have added another two tons to the 16 as above. Furthermore, the soil of S.554 has, before S.554 was planted, yielded an amount of fibre which may be estimated equal to the no-treatment yield of S.93, viz. to 5.5 tons of fibre per hectare.

To conclude, the author thus estimates that with sufficient potassium manuring, but without phosphorus and nitrogen, the old red soil, as it was in 1929, was able to yield a sisal crop of about 16 plus 2 plus 5.5 or 23.5 tons of fibre per hectare if cutting is stopped at the 93 per cent poling stage. This is about 9 tons of fibre, or about 28 per cent less, than the otherwise comparable yield of 32.34 tons per hectare in S.485 (cf. Table I), which was situated in a superior patch of fresh red soil after forest clearing, and which latter yield could not be improved by full manure in S.485, although it could be obtained in a somewhat shorter time. Said difference of 9 tons of sisal fibre may be attributed to deficiency of phosphorus and/or nitrogen in the old red soil as it was in 1929. Thus it appears that this soil, besides having been exhausted very badly as regards potassium, had also been exhausted to some extent as regards phosphorus and/or nitrogen, although the supply of these food substances in this soil was still considerable. This supply then was, for the more exhausted of these two substances, equivalent to about 23.5 tons of sisal fibre per hectare. Afterwards it will be shown that this most exhausted substance was phosphorus.

It was estimated above that S.554, in old red soil which had borne already a sisal crop of about 5.5 tons of fibre per hectare, will produce by liberally manuring with potassium only about 18 tons of sisal fibre per hectare until the 93 per cent poling stage. Thus important amounts of phosphorus and nitrogen must have been at the disposal of this S.554 soil at its time of planting. This phosphorus and/or nitrogen must, however, have been inaccessible for sisal to a large extent during the first three and a half years of S.554, because otherwise its yield rates could not have been so low during this time, as they are in Table II.

This time of low yield rates, i.e. three and a half years, may be called the lag period of S.554. The cause of this lag period may be either a direct unavailability of phosphorus and/or nitrogen or it may be some other limiting factor. It would have been possible to check this alternative by a sisal field experiment with the various possible combinations of potassium, phosphorus and nitrogen as treatments if only a sufficiently large soil area of the qualities as in S.554 had been available in 1937 when the question arose. The only such area available was provided by the untreated plots of S.93, which by 1937 had been lying fallow for about one year. This area was not large enough for a sisal experiment with the number of treatments desired, but it was just sufficiently large for such a tapioca experiment, tapioca and sisal forming the two chief crops of Soekamandi Estate. This tapioca experiment, T.503, was planted in January, 1937, and harvested in April, 1938. It thus fell in the middle of the lag period as in S.554. It was of a straightforward factorial design, with three potassium, three phosphorus and four nitrogen levels, and thus consisted of 36 manure treatments. It does not seem important to report here all its yield data. As relevant to the present purpose, those in Table III will suffice.

TABLE III

SOME DRY-WEIGHT DATA OF TAPIOCA STEMS IN EXPERIMENT T. 503

Yield in Tons per ha.	Treatments			
	Without	With (kg. per ha.)		
		N	P_2O_5	K_2O
8·0	—	120	104	432
5·2	Nitrogen ..	—	104	432
3·1	Phosphorus ..	30	—	216
1·1*	Potassium ..	0 to 120	0 to 104	—
2·7	Potassium alone..	—	—	432

*Mean of twelve treatments.

From the whole of the data of T.503 it can be inferred that the 8.0 yield of Table III is somewhat below its maximum, as a higher nitrogen level would have added a little to this yield, but that the other yields of Table III are approximately maxima.

It was estimated above that with liberal potassium manuring, but without phosphorus and nitrogen, sisal fibre yield in S.554 will be 18 tons per hectare until the 93 per cent poling stage, i.e. 41 per cent less than in S.485 on fresh red soil, which soil can be considered as having received a liberal full manuring. For tapioca, however, growing within the lag period as in S. 554, it can be seen from Table III that the omitting of phosphorus and nitrogen from the full manure decreases tapioca stem yield by more than 76 per cent, which value is 35 per cent more than the corresponding figure for sisal-yield decrease in S.554 if the whole sisal cycle is taken into account.

It may thus be inferred that the lag period in S.554 is due, at least to a considerable extent, to direct inaccessibility of phosphorus and/or nitrogen.

A further inference which can be drawn from the data of Table III is that during the lag period, as in S.554, comparatively less phosphorus is available than nitrogen, as, by the omission of phosphorus from the full manure, tapioca-stem yield is decreased by nearly twice as much as by the omission of nitrogen. Thus the lag period, as in S.554, is caused by unavailability of phosphorus, whereas the availability-position of nitrogen during the lag period remains undecided.

The following statements can now be made. If an old red soil, poor as it is regarding potassium, is further virtually completely exhausted as regards this food substance by a sisal fibre crop of about

5.5 tons per hectare without any manuring until the sisal dies from potassium deficiency, still a considerable amount of phosphorus is left in the soil and a comparatively much larger amount of nitrogen remains at its disposal. If thereafter sisal is planted, which is manured with potassium only, a sisal crop will be obtained of about 18 tons of fibre per hectare (until the 93 per cent poling stage), which yield is limited by phosphorus deficiency. Then still some nitrogen will be left in the soil. If then sisal is planted again which is manured with potassium and phosphorus a crop will be obtained of perhaps some 9 tons of fibre per hectare, which yield is limited by nitrogen deficiency.

An important question, awaiting an answer, is the cause of the unavailability of phosphorus during the lag period of S.554. The clue to this answer should be that the lag period is ended by potassium manuring during sisal growth. It cannot be seen from S.554 whether sisal growing is essential to put a stop to the lag period or whether potassium-manuring alone, without a crop, would have had the same result. Fortunately, the author has at his disposal some experimental data, which apparently solve this alternative.

In the first half of 1931 the author laid out some tapioca field experiments in a badly exhausted place of old red soil. They were arranged in blocks denoted T.52 to T.59. With some exceptions the plots within these blocks were planted three consecutive times with tapioca. The three corresponding periods lasted each about one and a half years. The experiments were thus finished in the second half of 1935. The object of these experiments was to investigate the effect of green manure (*Tephrosia candida* D.C.) and of stable manure, both with and without various combinations of artificial manures, on tapioca yield. The green manure grew during the first period and was dug into the soil before the second. Some of the plots lay fallow and were clean weeded during the green-manure period. The treatments relevant to the present purpose are those without green manure or stable manure, but which received either no artificial manure at all or only at the beginning of the first period. It is essential to the present purpose that, besides being very potassium deficient, the soil should be phosphorus deficient. That this was so is proved by the data of Table IV.

TABLE IV * †

YIELD OF FRESH TAPIOCA TUBERS IN TONS PER HA. IN T.52 to T.59 (*Partim*)

P_2O_5 in kg. per ha.	K_2O (in kg. per ha.) / Period	0	213	426
0	1st (Fallow) ..	—	—	—
0	2nd	23·4	40·4	37·8
0	3rd	8·1	11·5	8·8
57	1st (Fallow) ..	—	—	—
57	2nd	—	43·2	46·3
57	3rd	—	16·6	13·5

*Taken from "Groene Bemesting, Kunstmest en andere Factoren in Sisal-en Cassave- Productie". V. *De Bergcultureis*, 1937, No. 9, pp. 264–278.

†Manure spread over the soil, in the beginning of the first period.

The point now is to investigate the effect of leaving the soil fallow during the first period as compared with non-fallow, in both instances potassium manure being applied in the beginning of the first period. This point can be investigated in Table V. In this table the corresponding yields of the second and third periods have been summarized. These summarized yields, which thus do not include yield of the first period, will further be referred to simply as "yield" with a view to facilitating expression.

TABLE V

SOME YIELDS OF FRESH TAPIOCA TUBERS IN TONS PER HA. AS IN T.52 TO T.59

PERIOD	K_2O *			K_2O * †		
	0	213	426	0	213	426
1st ..	Fallow	Fallow	Fallow	20·6	40·3	41·8
2nd ..	23·4	41·9	41·6	20·7	45·3	50·6‡
3rd ..	8·1	14·5	11·2	5·5	14·6	23·2
Summarized yields of 2nd and 3rd period (=Yield)	31·5	56·4	52·8	26·2	59·9	73·8

*In those treatments, where potassium was applied, the following other plant-food substances were applied simultaneously per ha.; 53 kg. N, 42½ kg. P_2O_5, 45 kg. Na_2O.

†Taken from "Groene Bemesting, Kunstmest en andere Factoren in Sisal–en Cassava–Productie". VI *De Bergcultures*. 1937, No. 36, pp. 1290–1305.

‡It will be noticed that yields in the second period are higher than in the first. The cause is that in the second period there were two rain seasons and in the first (and third) only one.

It will be seen from Table V that, without any manure, yield is smaller where in the first period tapioca has been grown than where in the first period the soil has been fallow. This should be expected, as continued cultivation with tapioca without any manuring is known to exhaust the red soil. Where 213 kg. of K_2O per hectare were applied, yield is somewhat better with a tapioca crop in the first period than without, although an application of 213 kg. K_2O per hectare is only small for three tapioca crops. Where 426 kg. K_2O per hectare were applied, yield was much higher with a tapioca crop in the first period than without, notwithstanding the fact that the tapioca in the first period must have consumed a considerable amount of plant food. Since with sufficient potassium manure phosphorus was the limiting factor, more especially in the second and third periods, it thus follows that tapioca growing during the first period has increased the available phosphorus in the soil, i.e. it must have made phosphorus available that remained unavailable if the soil was left fallow during the first period. The inference from this is that in fallow land, manured liberally with potassium, unavailable soil-phosphorus is not made available, or at least to a much lesser extent than in land planted with tapioca. It might here perhaps be remembered that the land meant here is badly exhausted old red soil.

The next deduction is that in S.554 the improvement in availability of soil-phosphorus has not been due to potassium manuring as such, but to potassium manuring of a soil planted with sisal.

It may now be suggested that it is the excretions of sisal roots in the case of S.554 and of tapioca roots in the case of Table V which transform unavailable soil-phosphorus into the available form. This, however, seems improbable, because on the one hand it took the sisal of S.554 three and a half years to accomplish what the tapioca of Table V accomplished in one and a half years; whereas on the other hand the volume of tapioca roots per unit of soil area is not large as compared with same of sisal. Thus the author thinks that the only reasonable explanation for the improvement in available-phosphorus conditions of a potassium-poor old red soil, planted with either sisal or tapioca, is the increased enrichment with organic matter by manuring under said conditions a crop liberally with potassium, as compared with non-manuring. Such enrichment is much faster for tapioca than for sisal because sisal, being regularly cut, leaves in the soil only fragments of leaves and further pieces of dying and decaying roots; whereas in the case of tapioca the soil is enriched by a heavy leaf fall, by pieces of stems (the bulk of the stems was removed from the soil in the experiments), pieces of tubers overlooked in harvesting

and all the roots after harvesting. This explains why the effect of tapioca on phosphorus availability was reached in about one-third of the time needed by sisal.

The following statement can now be added to those above, relating to plant-food exhaustion. By growing sisal in the old red soil without any manure the real phosphorus exhaustion is preceded by an unavailability effect on phosphorus, resulting from exhaustion as regards organic matter, this latter being due to severe exhaustion as regards potassium.

It seems improbable that the organic matter as such has transformed unavailable soil-phosphorus into available, at least not to an appreciable extent. It seems much more probable that micro-organisms, finding energy in the augmented organic matter, probably assisted by improved potassium conditions of the soil (on account of potassium manuring), have been able to consume soil phosphorus which was unavailable for sisal or tapioca, and have afterwards after their death and decay supplied this phosphorus in an available form to sisal or tapioca.

The author believes that the experiments reported here prove in a rather explicit way the importance of organic matter additions, besides food additions, to severely exhausted soil, whereas such importance should be valid also under conditions of lesser soil exhaustion and probably even under quite normal conditions although, maybe, to a lesser extent. This importance of organic matter may, at least to some extent, be identified with what the German agricultural research worker calls *Bodengare*, or what the German peasant calls *Die Alte Kraft des Bodens*, or what in certain recent Dutch agricultural literature is called *Bodemstructuur* or what Prof. J. Hudig, of Wageningen, Holland, calls "organic buffer" and/or "biologic buffer" of the soil. There may be many other similar expressions which apparently all centre in the same principle, namely, that organic matter—more properly "decomposable" organic matter—in the soil is of great assistance in conditioning the plant food contained in the soil in such a way as to be most suitable to plant growth.

APPENDIX

Statistics of Experiments

General

The first field experiments with sisal at Soekamandi proper were planted towards the end of 1923, at the rate of about 6,000 plants per hectare, the plots consisting usually of 120 plants. There were usually eight replications, while the standard error was usually from about 5 per cent to about 10 per cent of the mean. Later the number of replications in this type of experiment was increased to twelve, which reduced the standard error considerably. In said type of experiments the number of treatments was usually small, as a rule two to four. Similar experiments have been laid out up to recently.

However, already in 1925 experiments were begun with few replications, but with many treatments. In the beginning they were (outside) pot experiments, in some cases the pots being large, viz. up to 1.68 m^2, and being built of masonry within the soil. Later, most of this type of experiments were field experiments with few replications (say, five or even only one), and many treatments. In one case the number of treatments is even 169 and the number of replications five. In some cases, however, the number of replications in this type of experiments is rather large (say, eight) or even larger, viz. 16.

Further there is a large set of field experiments, laid out some ten years ago, with very large plots, narrow and long, in which a good correlation occurs between yields of adjacent plots. Their outlay is *a b b a a*, etc., which eliminates soil heterogeneity to a large extent on account of the reversed direction of differences within consecutive pairs of plots.

In the old red soil the experimental area had to be very restricted and the number of replications very small until 1932. Experiments after one sisal cycle had of course also after 1932 to be conducted with very few replications. A large advantage in this exhausted soil was, however, that already as long ago as in 1925 the very uniform plots could be chosen on account of the appearance of their previous natural vegetation, which, as is well known, exhibits on exhausted land large differences between parts of different fertility, even when the latter differences are comparatively small in an absolute sense.

In the experiments after one sisal cycle the choice of the plots could be made even more severe, viz. on account of the previous experimental results. It will be noticed that neither in case of original, natural vegetation nor in case of a previous sisal cycle, the uniformity choice of the plots is much influenced by weather conditions, as changing from year to year, which may be a factor of importance with short living crops, being used as uniformity criterion.

It will be understood that the uniformity choice, as described, was strict only with small-size experiments, while it was not urgent, neither always possible, with the later experiments containing large numbers of plots.

Particulars as regards Part IV

(1) *Fourth and Fifth Yield Rows of Table I.*—S.93 consists of 32 plots with 16 treatments. The treatment of the fourth row has two and the fifth row four replications. The mean of the total cycle fibre yields per plot is for the fourth row 190.5 kg. and for the fifth row 54.2 kg., the t for the treatment difference being 10.64, whereas t is 4.604 for $P=0.01$.

(2) *First, Second and Third Rows of Table I.*—These treatments have not been replicated. However, their yields do not differ much from those of the fourth row and equally from those of the other three sole-potassium treatments. The four sole-potassium treatments differ in green-manure treatment. Each sole-potassium treatment has been replicated twice. The standard deviation per plot of the total cycle fibre yield within these four treatments is 7.9 per cent of their mean.

Thus 7.9 per cent may be considered as the standard deviation of the total cycle fibre yield of the first, second and third rows. It will be noticed that no far-reaching use has been made of the data of these rows.

(3) *Fourth Row of Table I.*—Under (2) it has been mentioned already that the four sole-potassium treatments, which were each twice replicated, do not differ much the one from the other. Thus the standard deviation per plot of the total cycle fibre yield of the fourth row may be considered to be 7.9 per cent of said yield and thus the standard error 5.7 per cent of said yield.

(4) *Sixth Row of Table I.*—The number of corresponding plots was originally two, one with the chloride form of potassium and the other with the sulphate form. After the fifth cut each of these two plots has been divided into two sub-plots, in each case the manure in the one sub-plot being spread over the soil surface and in the other sub-plot the manure being buried in shallow ditches. For each sub-plot two cut-yields are available. The

total yields of the two cuts are very similar for the four sub-plots. The standard error of their mean is 2.5 per cent of that mean.

(5) *Seventh Row of Table I.*—The respective treatment has been replicated twelve times. The standard error of the mean of the total cycle fibre yields is 1.98 per cent of that mean.

(6) *Table II.*—The data of this table are self-sufficient as regards statistical significance. After equalizing the maxima of each series at 100 and after expressing the other members within each series as percentages of their respective maxima, the two series become, as far as they have to be compared—

	29	39	60	72	100	
	9	12	25	28	76	(100)
Differences ..	20	27	35	44	24	with $t=6{\cdot}7$

Whereas for $P=0{\cdot}01$ t is .. ..4·604

(7) *Table III.*—The 36 treatments of T.503 were not replicated. However, little or no effect was reached without potassium. Thus the twelve treatment data without potassium may be used for statistical analysis. The standard error of the mean of said twelve treatments is 0.08. The standard deviation per treatment is 0.28. The difference between the total-manure treatment and the non-nitrogen treatment of Table III is about ten times said standard deviation per treatment.

(8) *Significance of Potassium Effect in Table IV.*—It should be proved that 23.4 is significantly smaller than 40.4 together with 37.8. The first of these data is the mean of four replications and the two latter are each a mean of two replications. Without discounting for the yield difference as due to difference between potassium levels, the t of the potassium effect is 2.523, whereas for $P=0.05$ t is 2.447. For larger significance of potassium effect for tapioca in an old red soil of nearly equal fertility refer to (9).

(9) *Significance of Phosphorus Effect in Table IV.*—This effect is not significant. It can, however, be proved to be very significant under similar soil conditions, as applied to Table IV.

T.485 is a large tapioca experiment, planted in the beginning of 1936 when sufficient means were available for extended experimental work in the old red soil. T.485 is a rotation experiment of tapioca with *Centrosema pubescens* Benth. and with *Leucaena glauca* Benth. For each sort of green manure the third-order blocks contained in the first rotation period one tapioca plot and three green-manure plots. For each green manure sort, eight third-order blocks, each with different artificial manure treatments, constitute a second-order block. Two second-order blocks, each with a different green-manure sort, form a first-order block. The first-order blocks are eight times replicated. In each block of every order each item is of course randomized within its own block. In the period beginning in 1936 there were, out of the total of 512 plots, sixteen replications of each of the following treatments applied to tapioca:—

— — —	(without manure),
— — K	(with sole-potassium),
— P K	(with potassium and phosphorus).

Part of T.485 was situated in soil that had borne two consecutive experimental tapioca crops, whereas some marginal strips had borne during said period natural vegetation. Leaving out the latter strips, there remain for each of the mentioned artificial manure treatments eleven replications. In units of 0.1 ton per hectare, and not discounting for block differences, the analysis for the fresh tapioca

roots, as harvested in 1937, i.e. about a year and a half after planting, is as follows:—

Sort of Variation	d.f.	Sum of Squares	Variance
Total ..	32	370,436	—
(– – K) — (– – –)	1	59,422	59,422
(– P K) — (– – K)	1	72,347	72,347
Error	30	238,667	7,956

The variance-ratio potassium-effect error is 7.469 and the corresponding value for the phosphorus-effect (in the presence of potassium) is 9.1; whereas said ratio is 4.17 for $P=0.05$ and 7.56 for $P=0.01$.

The yields of fresh roots in tons per hectare are for the above treatments in the order as above: 27.0, 37.5 resp., 44.0. The non-manure treatment does not differ much from the corresponding yield in Table IV.

(10) *Table V*.—It is sufficient to prove the significance of the difference for one yield of the fallow series with the corresponding yield of the non-fallow series. This is done for 23.2—11.2. Each of these values is a mean of eight replications. The t for the difference is 3.2, whereas t is 2.145 for $P=0.05$ and 2.977 for $P=0.01$.

Reviews

AN AFRICAN SURVEY: A STUDY OF PROBLEMS ARISING IN AFRICA SOUTH OF SAHARA, by Lord Hailey, G.C.S.I., G.C.I.E. (Issued by the Committee of the African Research Survey under the auspices of the Royal Institute of International Affairs); pp. xxviii + 1838; O.U.P., 1938; 21s.

"The sole object for undertaking the Survey," says Lord Hailey, "was the hope that it might prove of some service to the Powers who have possession of territories in Africa, and of some benefit to the African people." This modest aspiration is more than fulfilled in the subsequent survey, which was conceived and conducted on a truly grand scale, taking into account every important aspect of the problem. It is a great study, produced in the remarkably short space of five years, and has no equal in the modern literature on Africa. Few men, even among those who have spent the whole of their service in Africa, can have obtained the grasp of the essential facts of the continent in the way that Lord Hailey, who served India, shows he has done in this concentrated and comparative study. One is amazed by the range and objectiveness of the book, which gives one a vision of Africa, its problems and institutions as a whole, and the influence on development of the various Colonial Powers who so largely control the affairs of the continent to-day. It is emphasized that "these powers are engaged in a common task, though in some respects with widely different methods of approach." Concerning these methods, there is one matter in which the French and Belgians appear to have been more successful than the British; that is, in the training and employment of educated Africans in the administrative and technical services so as to relieve European officers of routine duties.

As it is impossible in a short review to indicate the scope of this comprehensive survey of 1800 odd pages, it must suffice to deal chiefly with Chapter XIII, Agriculture, the eight sections of which almost constitute a book in themselves and deal with the agricultural problems of the native and European in both British and non-British territories. The chapter opens with an introduction aptly describing the basic methods of native agriculture and goes on to deal with the cattle-owning tribes, the introduction of new crops and animals, the recent development of native agriculture and the position occupied by

game in the native food supply. Two sections, one on native and one on European production follow, each of which contains a long descriptive catalogue of crops grown. In looking through this list one is struck by the number of major crops which are introductions to Africa, and thus constitute a denial of the charges that the African does not change and that introduced crops are never a success. Incidentally, some of the statements made regarding various crops are likely to be questioned by agriculturists, while the fear expressed (p. 889) lest the so-called European potato should oust the sweet-potato in certain areas would seem to be groundless. In the section on Agricultural Production by Europeans, the character and extent of this industry in various parts of Africa is reviewed and its dependence on an easy supply of cheap native labour emphasized. In Kenya, it is pointed out, European exports exceed native. The Survey then goes on to animal husbandry, dealing with the subject from the standpoint of animal diseases and preventive measures, the meat industry, hides and skins, wool and dairying. Sections V and VI, which follow, will be regarded by many readers of this Journal as the most important in the book, as they treat of agricultural research and the improvement of native agriculture. The chapter concludes with a section on the improvement of animal husbandry and, finally, some further conclusions.

In the section dealing with agricultural research Lord Hailey, while fully praising the research work being done in the different African territories, points out what is probably the greatest weakness in the organization of agricultural research not only in East Africa but elsewhere in the continent, i.e. the lack of co-ordination of research policy as a whole in the sense in which the word would be ordinarily used. He adds: "It is difficult to believe that under this system it is possible to make the best use of the small resources available for research into problems of agriculture and animal husbandry." This system is compared with that of the French, where research is under the direction of scientific institutions in Paris which, while making for closer co-ordination of effort and economy of staff, leaves less scope for individual initiative and takes less account of the variety of needs arising from local circumstances. The recent foundation of the Inter-territorial Coffee Research Committee can be regarded as a laudable attempt to co-ordinate work on at least one crop in East Africa.

In his penultimate chapter Lord Hailey pleads for considerably more research and suggests that an adequate fund should be created by the Imperial Government, preferably in the form of a non-lapsing grant-in-aid, to be administered by a committee of the Privy Council or the Economic Advisory Committee, whose duty it will be to devise, in association with the appropriate scientific authorities, "the measures for making the most profitable use of the agencies concerned in any one branch of study . . . and for maintaining the necessary contact between them and the agencies concerned with kindred branches of work." Such a body would be well suited, it is thought, to attract the assistance of the universities which, it is pointed out, have so far played but a small part in the special study of matters concerning the colonies.

Concerning the improvement of native agriculture, it is rightly stressed that the most urgent problem is the maintenance of soil fertility with extensive recourse to shifting cultivation, which is aptly described elsewhere in the book as "less a device of barbarism than a concession to the character of the soil . . ." Green-manuring, composting and mixed farming

are mentioned as possible methods for achieving the desired end.

Referring to the improvement of native crops, it is pointed out that if a continuous supply of sound planting material is to be maintained a considerable extension of seed farms is necessary. The provision of holdings where new methods can be tried out under proper supervision is advocated. These holdings would also serve as a training ground for Africans needed as assistants in agricultural departments and as demonstrators in native areas or as advisers to native authorities.

While the need for the improvement of cash crops is admitted, the primary need is shown to be improvement in subsistence crops so as to maintain or increase production in spite of the difficulties caused by the changing conditions brought about by the introduction of cash crops and the employment of large numbers of the male population on mines and estates.

Malnutrition among Africans needs "scientifically based measures for the improvement of diet, but pending the results of research into the problem, agricultural research," it is pointed out, "can be directed towards improvements in the yield of crops grown by natives, and towards popularizing introduced food plants."

There is much that concerns agriculture outside Chapter XII of the Survey, references to which can be traced in the excellent index (p. 1667 *et seq.*), sub-head Agriculture, where no less than fourteen columns are occupied by agricultural references.

A sustained effort is needed to absorb even part of this huge survey, but the reader who does so will be rewarded by the feeling that he is thoroughly well informed on any particular African problem he chooses to study, while in reading those sections which are not purely descriptive he will find the labour a very pleasant and stimulating study.

A. G. H.

THE COCO-NUT, by J. S. Patel, M.Sc., Ph.D. (Government Press, Madras; vii, 313 pages; price 3 rupees 12 annas).

The author of this monograph has attempted to collect in a concise yet comprehensive manner all the information of importance concerning the coconut palm. The works of Sampson and Copeland are freely quoted, and results of many other workers, previously scattered in numerous journals, are now for the first time summarized within one cover. In addition there are incorporated the results of eighteen years of coco-nut research by the Madras Department of Agriculture. Although some of these results have already been reported in Madras departmental publications, they are not readily accessible to the public or to other research workers, and are therefore recorded in some detail in the present volume. The book opens with a brief summary of the world distribution of the coco-nut palm, the climatic conditions under which it is grown, and the cultural practices employed in different countries.

Subsequent chapters, illustrated by a number of excellent photo-micrographs, describe in detail the structure and development of the root system, the stem, the leaf and the inflorescence, and discuss the influence thereon of certain environmental factors and cultural practices. A mass of original biometric data and numerous analyses and correlations thereof are recorded. Amongst the most interesting and practically important conclusions arrived at by the author are:—

(1) Rapid linear growth of the stem and high leaf number are both associated with high yield and early bearing. Therefore, in selecting mother trees from amongst palms

of equal age which have had identical treatment, one should choose, *ceteris paribus*, tall plants with many leaves.

(2) Seedlings that germinate early usually have a greater number of roots, increase more rapidly in height and girth, and produce leaves faster than slow germinating seedlings. Therefore reject the latter.

(3) Round nuts tend to germinate earlier than oval ones.

(4) The best percentage germination is obtained by planting heavy nuts, with moderately thin husk, taken from large bunches.

(5) Yield is *not* correlated with any of the following factors: number of leaflets, length of leaflet-bearing portion of leaf, total length of leaf including petiole, length of petiole, thickness of petiole, cross-sectional area of petiole, number of vascular bundles in the petiole, girth of petiole.

The section dealing with manuring and cultivation is a forcible reminder of how little we know about these important subjects in relation to the coco-nut. The author is able to quote only two papers by other workers on the manuring and cultivation of mature coco-nuts, and even these are inconclusive. The Madras experiments here reported are of considerable interest, but are not easy to interpret, owing partly to unsatisfactory lay-out and partly to the inadequacy in some instances of the records of tree performances prior to the initiation of the experiments. (These trials were started about twenty years ago, before the statisticians had revolutionized experimental technique.) But at least one or two points of importance emerge. Firstly, trees with a low average yield respond more to manuring that do trees with a high average yield. For instance, individual tree records were kept of all the trees on one block which was cultivated but not manured for four years, and then cultivated and also manured for six years; and the trees were grouped according to their yields over the unmanured period into "poor bearers" (less than 30 nuts per annum), "medium bearers" (30 to 50 nuts) and "heavy bearers" (80 nuts or more).

The average yields over the manuring period, when compared with the average over the unmanured period, show that the poor bearers improved 145 per cent, the medium bearers 27 per cent, and the heavy bearers failed to improve at all. But even so, the heavy bearers yielded four and a half times as big a crop as the poor bearers, the figures being 113 nuts per tree per year and 25 nuts per tree per year respectively for the manuring period. The equivalent figures for the unmanured period were 116 and 10 nuts per tree per year. The medium bearers likewise only increased from 53 to 67 nuts per tree per annum, and were thus still a long way behind the heavy bearers. The overwhelming importance of seed selection is amply demonstrated by these results. But this is poor comfort for the owner of a plantation which has already been planted with unselected material. His problem is to make the best of a bad job and get the maximum economic yield from the mixed population of good, bad and indifferent trees. The Madras experiments indicate that he can raise yields by manuring; whether it is economic to do so must depend on local circumstances, current prices, etc.

A second way in which he can improve yield is by cultivation. A Madras experiment showed that cultivation alone considerably raised the yield of nuts, and gave better results than applying manure in trenches but leaving the rest of the

plot uncultivated. The effect of the elimination of weed competition for food and water is likely to be even greater in East Africa than in Madras, which has a much heavier rainfall and a relatively short dry season, and we should like to see more planters in this country give cultivation a trial, even if only on a small scale to start with. It must be noted, however, that no great improvement should be expected for about two years. As Patel points out, the yield is largely governed by the number of spadices opened, and the number of female flowers produced; and the development or abortion of spadices within the bud is determined by conditions twenty-eight months prior to harvest; similarly, the primordia of the flowers are formed about two years before harvest. It is not the current crop which is much affected by cultivation but the crop which, at the time of the cultivation, is being differentiated in the tender tissue of the cabbage.

A fairly full account is given of the manufacture of, and trade in, copra, coconut oil and cake, and coir, except that the subject of the design, construction and operation of copra drying kilns is rather briefly treated. The manufacture of coconut shell charcoal is also dismissed in a few lines. References to original papers on these subjects are, however, quoted for those who need fuller information.

There are also concise chapters on tapping, on pests and diseases, and on abnormalities of the coco-nut. A bibliography of nearly two hundred titles, and a moderately full index complete a volume which is well worth the attention of all agriculturists who have to deal with coco-nuts, though its main appeal will, we think, be to the experimentalist rather than to the planter. R. B. A.

SPRAYING MACHINERY

For Applying all Washes and Dusts, Limewash, Creosote and Disinfectants.

There is the right machine for every job—ask a friend who is using a **VERMOREL** Sprayer.

VERMOREL HEADLAND PUMP.

Prices from **£10-0-0**

Or complete with 30 ft. of Special Tar Wash Resisting Hose, 18 in. Variable Spray Lance (or Gun), **£12-8-0** Ex Warehouse London.

No. 22—THE VERMOREL HEADLAND PUMP

A Sprayer which has met a general demand

Special points: Strongly made, but light in weight, makes **high-pressure** spraying possible with a low-priced machine. **Pressure up to 220 lb. per square inch,** with ordinary nozzle or **150 lb.** with a Spray Gun. Not affected by tar-oil, lime-sulphur, etc. Weight complete 94 lb. Length 4 ft. 6 in. Width 1 ft. 10 in. Supplied complete with 8 ft. suction hose, with strainer and pressure gauge. Can be supplied with any length of delivery hose, and a large variety of Variable Spray Lances (or Guns), of which full particulars are given in our catalogue.

ALL TYPES OF WET AND DRY SPRAYERS MADE AND STOCKED.
CAPACITIES FROM 2¼ PINTS TO 220 GALLONS.
PRICES FROM 4/- to £172.

Complete catalogue and list of stockists in East Africa from—

COOPER, PEGLER & Co., Ltd.

31/31a Clifton St., Finsbury Square, LONDON, E.C. 2

The Botanic Gardens, Entebbe

By A. S. THOMAS, *B.Sc., M.Sc., A.I.C.T.A., Botanist, Department of Agriculture, Uganda*

Forty years ago, in 1898, Alexander Whyte, M.A., F.L.S., was appointed Curator of the Botanic Gardens, Uganda, "about to be established for the better examination and development of the agricultural resources of the Protectorate." The site of the gardens was at Entebbe, the seat of government and at that time the main European settlement in the country. The forest was cleared and in the succeeding years the gardens acted as a centre for trial of all the economic plants that were introduced. Even before 1901, when the railway reached Kisumu, seeds of fruits such as oranges, lemons and mangoes had been planted, together with many European vegetables.

In the first decade of the twentieth century many consignments of plants were received from the Royal Botanic Gardens, Kew, from India, Ceylon and the West Indies. The difficulties of introducing the various species were very great for, although the plants might be carefully established in Wardian cases, yet they suffered from extremes of temperature on the journey—the heat of the Red Sea and the coast, followed by the cold of the East African highlands. Nevertheless, within ten years of the inception of the gardens, many of the tropical economic plants had been established and some had shown very good results. In fact, the great promise of the crops in the gardens was largely responsible for the beginning of the plantation industry in Uganda.

A single plant of para rubber (*Hevea brasiliensis*) from Kew was established in 1901 and made excellent growth from the first. This original tree still exists and now is nine feet six inches in girth at a height of two feet above the ground. A case of seedlings, also from Kew, was planted in 1903, and subsequently many thousands of seeds were imported; the seedlings were used for making plots at Entebbe, for roadside planting, and for sale to planters. Other rubbers—*Castilloa elastica, Funtumia elastica* (which afterwards was found to be native), and *Manihot Glaziovii* (Ceara)—also were introduced and tested.

Cacao (*Theobroma cacao*) was first planted in 1901, when two small plots were established, and there were several other consignments from Kew and the West Indies. This crop also showed considerable promise, the first plot fruiting in 1905 and its seeds being used to extend the area under the crop at Entebbe and for distribution.

Coffee was also tried in the gardens. A single plant of *Coffea canephora* (Robusta coffee) was introduced in 1900, although the species was abundantly cultivated on native farms in the neighbourhood. Arabica coffee was started at the same time; the first consignment of seed came from Nyasaland, and a plot of two acres was in fruit by the end of 1903, during which year other varieties—Blue Mountain and Guatemala—were introduced.

Tea was an early introduction, for Whyte, who had worked in India and Ceylon, considered parts of the Uganda Protectorate "singularly well adapted for the cultivation of the tea plant." The first plants were received in 1900 and another batch in 1904, but they were of low *jat* and made such poor growth that visiting planters considered that the crop would not be a success. It was a great pity that, while cacao and rubber showed such

promise and were soon planted on a large scale, the early results with tea were discouraging; for rubber and cacao have proved to be uneconomic crops in Uganda while tea should be very profitable. Undoubtedly the reason lay in the poor variety that was tried, for good Indian *jats* planted in recent years at Entebbe have made strong growth.

Pioneer work in essential oil production was done in order to conrol tsetse-fly. The land beside the Lake was cleared and by 1907 fifty acres of it had been planted with lemon grass (*Cymbopogon citratus*). Distillation was commenced in 1908, but after some years the project proved unprofitable and was discontinued.

Fibres were also tried. In 1903 ramie (*Bcehmeria nivea*), sisal (*Agave sisalana*), and Mauritius hemp (*Furcraea gigantea*) were introduced; all showed some promise and large trials of the Mauritius hemp were made, but although a bulk of leaves was produced the extraction of fibre was uneconomic. Experiments with cotton were made in the gardens for several years, but there was never much success, and most of the early investigations on this crop were carried out on plantations at Kampala and Jinja.

Many decorative plants also were introduced, and the list of species in the Entebbe gardens, published by Mr. M. T. Dawe in 1904, shows what great progress was made under the direction of those who worked at Entebbe in the early years —Mr. Whyte, Mr. John Mahon, Mr. E. Brown and Mr. Dawe himself. The old Botanical, Forestry and Scientific Department was responsible not only for the gardens, but also for the development of resources of timber, of native and introduced agricultural products and for the meteorological observations throughout the Protectorate. Therefore, when the trade of Uganda developed, it was decided to create a Department of Agriculture distinct from the Forestry Department, and in 1910 the two were separated. Most of the agricultural experimental work was done at Kampala, but as the oldest rubber and cacao plots were at Entebbe the Forestry Department continued to keep records of them, to make trials of tapping rubber and to supply seed in large quantities, especially to the European plantations which were then being opened up. The size of the gardens was reduced, and many parts were planted with grass, but the returns from the sale of seeds and of rubber more than paid for the upkeep in some years.

In 1917 it was decided that it would be better if all experimental work on plantation crops was transferred to the Department of Agriculture, who took over the plots of cacao and rubber, although the Forestry Department retained part of the gardens for nurseries and experimental plantations, including a plot of oil palms. In 1927 the oil palms were transferred to the Department of Agriculture, which subsequently took over the whole area.

The gardens have been extended in recent years, until at present they cover all the land available and have a total area of about ninety acres. The site has great natural beauty and consists of lawns sloping to Lake Victoria whose waters, bright blue in sunny weather, make a fine background to the gardens. Many fine indigenous trees, some left as single specimens and others in small patches of forest, add greatly to the effect; not only do the forest patches afford the shady conditions required by many plants but also they harbour a very large and varied bird population, which is as interesting as the flora of the gardens.

The climate is relatively equable, with an annual rainfall of about 60 inches,

well distributed, while the proximity of the Lake ensures an even atmospheric humidity. The temperature varies between fairly narrow limits—the mean maximum is about 79° F. and the mean minimum 63° F., while it is seldom that temperatures below 55° F. or above 85° F. are recorded; in consequence, a great range of tropical and subtropical plants may be grown.

In contrast to the great advantages of the position, there are several drawbacks. The soil is mostly a heavy loam, but is uneven; in many places there are outcrops of rock or murrum, while, on account of the slopes, much of the top soil has been washed away. The lowest parts of the gardens are only a few feet above the level of the lake, and often are waterlogged in spite of careful drainage. In fact, drainage is a great problem throughout the gardens, for provision must be made for the storm water from the township above and, in wet seasons, springs break out in many places on the lower levels. The native fauna is very interesting, but monkeys and squirrels sometimes do much damage, while the hippopotami from the Lake at intervals browse in the gardens, showing a distinct preference for newly planted lawns, in the soil of which their footprints are deeply implanted. The proximity of the Lake also entails high winds, sometimes reaching gale force, which do much damage; in April, 1936, a whirlwind passed through the gardens, uprooting or snapping off many of the finest trees, and months of work were required to obliterate the destruction that was caused.

The climate of Uganda is too cool for the profitable production of cacao and rubber, the two crops on which most work was done at Entebbe; much of the cacao and rubber therefore has been removed, but small plots of both are retained for demonstration. At the present time the oil palm (*Elaeis guineensis*) is the most important crop in the gardens; the oldest plot, planted by the Forestry Department in 1921 with seed from the wild oil palms in the Semliki Valley, consists mostly of poor types. The progeny of some of the better palms on the original plot show promise of yielding well, while the young palms raised from the seed of selections at Calabar (Nigeria) and Serdang (F.M.S.) are growing and fruiting well. It is very improbable that there can ever be an export of oil palm products from Uganda, but the oil would be a valuable addition to native diet and might be useful for the local soap industry.

Other economic plants which have been planted in recent year include tea. A segregated plot of variety Betjan has been established for seed supply in the gardens and another plot of variety Dhonjan at Kitabi nearby. The growth of both has been very strong, in contrast to the stunted habit of the China *jat* introduced at the beginning of the century.

Many spice plants are grown, though some—for example, allspice (*Pimenta officinalis*), bay tree (*Pimenta acris*) and nutmeg (*Myristica fragrans*)—are represented only by young plants. A plot of pepper (*Piper nigrum*), planted to climb on some old rubber trees, has grown vigorously and flowers well, but to date (five years after planting) has produced no fruit. Vanilla (*Vanilla planifolia*) flourishes in the gardens and will be planted on a larger scale there, as it shows promise of being profitable in parts of Uganda.

The most important of the collection of drug plants is *Cinchona josephiana*, of which a quarter-acre block, planted at Kitubulu in 1921 by the Forestry Department, has produced bark of high quinine

content, one sample containing 14.75 per cent (as sulphate). This area is administered under the gardens, and affords a valuable source of seed supply. *Hydnocarpus anthelmintica* and *H. Wightiana*, whose seeds furnish the Chaulmoogra oil used in the treatment of leprosy, have grown and fruited well in the gardens, and individual tree records are kept.

In addition to the economic plants which are grown in quantity, small numbers of others are grown in order that observations may be made of their relative value under Entebbe conditions. A collection of wild Robusta coffees from thirteen localities in Uganda and from the south of the Anglo-Egyptian Sudan has been established, and a collection of ten Arabica coffee varieties is showing interesting differences in growth; for example, the Harar type, which shows so much promise in Kenya, is stunted at Entebbe by the attacks of leaf spot (*Cercospora coffeicola*).

Tropical fruits are well represented in the gardens; of some genera, for example Eugenia and Psidium, there are many species. Budded citrus varieties grow fairly well; grafted trees of Indian mangoes bear good crops, but the temperature is never high enough for the complete ripening of the fruit, which does not acquire a bright colour. A number of species of fruit trees have not yet reached the fruiting stage, for that may take many years; the solitary mature specimen of mangosteen (*Garcinia mangostana*) was sixteen years old before it fruited.

An attempt is being made to concentrate the work on economic crops in the north side of the gardens, in order to leave the remainder free for landscape effect which, to the average visitor, is the more striking aspect of the gardens. A system of motor roads has been made to allow easy access to all parts, but many of the footpaths have been grassed over in order to accentuate the main beauty of the gardens—the great stretches of lawn.

The records reveal that most of the lawns originally were planted with French grass (=Bermuda grass, *Cynodon dactylon*), yet little trace of that species may now be seen, for the Cynodon has died down and has been replaced by a sparse poor turf of coarser grasses, many of which have undesirable tufted growth. In 1933 several small observation plots were planted with different grass species in order to test their relative value for lawn-making at Entebbe, and of these only two have remained relatively free from weeds—the native *Brachiaria decumbens* and the introduced *Paspalum notatum*. The growth of both these grasses is rather coarse at first, but they are being used as the best available for lawns on a large scale under the conditions at Entebbe.

Mention has been made of the fine trees which add so much to the beauty of the gardens. The native species are especially magnificent. Of these the most important are the tall spreading *Piptadenia africana*, the large rounded *Canarium Schweinfurthii*, *Antiaris africana* with its long slender bole, and the compact dark-foliaged *Pseudospondias microcarpa*. There are also good specimens of many exotic trees introduced early in the history of the gardens—*Eucalyptus* sp., *Acrocarpus fraxinifolius*, *Castanospermum australe*, *Delonix regia* and *Cassia javanica*. Other smaller trees which are beautiful in flower include the indigenous *Spathodea nilotica*, *Monodora myristica*, and *Erythrina abyssinica*, in addition to many exotics, especially species of Cassia and Erythrina.

While many of the specimens formerly were planted wherever there was space, in recent years an attempt has been made

to place them in families, or sometimes in genera; groups of conifers, of palms, of *Erythrina* sp., *Cassia* sp., and of bamboos, etc., have been assembled. The bamboos at present are untidy, for all the specimens of *Bambusa vulgaris* var. *aurea*, the most common in the gardens, are now coming into flower and, as usual with bamboos at that stage, are dying.

Some of the natural features have been utilized for special groupings. The largest outcrop of rock is planted with succulent plants, especially *Opuntia* sp., *Euphorbia* sp., and *Agave* sp., while a dry rocky bank has been used for a separate collection of *Aloe* sp. One patch of forest, the fernery, contains a large number of native ferns, among which the tree fern, *Cyathea Dregei*, is prominent. A recent extension of the gardens, below the Secretariat, is being reserved for native plants, while on the bluff nearby the short natural grassland and tall red anthills effectively contrast with the blue water of the Lake. The scattered flower beds have proved difficult to maintain when time for supervision is limited, and therefore many of them have been grassed over, with the exception of those containing the large collection of Canna varieties. In other parts of the gardens recourse is had to woody plants, such as varieties of Bougainvillea or Hibiscus, to provide the needful colour. Herbaceous and annual plants are now being massed in a large double border near the new nursery, traversed by a long pergola for climbing plants.

The nursery itself is a very important part of the gardens, for in it many thousands of fruit trees and of decorative plants are raised each year for distribution throughout the Protectorate. Plants from the Botanic Gardens have contributed largely to the attractive appearance of the up-country stations in Uganda, and introductions are continually being made of other plants of potential value, either economic or decorative.

Considerable progress has been made with the listing and labelling of all the plants. The catalogue, which is far from complete, already contains about nine hundred species, and the collection is being continually increased. It is hoped, however, that in the near future it will be possible to publish a plant list to show what may be offered in exchange to the other botanic gardens throughout the world who have so generously supplied material to Entebbe.

The Management of the Dairy Herd on an Arable Farm

By S. D. WHETHAM, *Greenhill Farm, Njoro, Kenya Colony*

The most outstanding point in the evolution of farming is the present-day tendency away from the old-fashioned idea of the "one-crop farm" and the "dairy farm" towards their combination in the "mixed farm," the two main components of which are the dairy herd and the arable crops. They must not be regarded as separate components but should be welded together to the mutual benefit of both.

The first and most obvious point of collaboration arises on the question of manure, and, incidentally to this, one thinks of movable milking bails, movable calf-pens, and small well-cropped paddocks; in short, any device in the management of the dairy herd which will concentrate the manure of the animals and allow of only a minimum wastage of this precious material.

Milking bails should be surrounded in front with a *boma* consisting of, say, three strands of barbed wire, and be of a size sufficient to hold the herd comfortably without overcrowding. The cows await their turn for milking in this *boma* and drop their dung there. They pass into the milking bail, are milked, and pass out into the paddock. It is a good idea to keep two movable salt pans in front of the bails, both for the good of the cows themselves and also to collect the manure caused by the congregation round these pans. Hay should be laid down daily on the floors of the bails themselves and the manure collected spread about the more unfrequented parts of the paddock.

The bails, which are run on sleighs, should be moved from time to time across the paddock and a new collecting *boma* installed, the site of the previous one being run over with a drag harrow to spread the dung around. A diagram of a suitable milking bail is attached (Fig. 1).

Movable Calf Pens.—This is not the place to enumerate the great advantages to be gained in health, cleanliness and facility of segregation by the use of movable calf pens. These points cannot be too strongly stressed, but the value of these pens for manuring purposes is also very high. Place them in lines, one calf only to each hut, and move them forward one point every two days. The floors should be plentifully lined with hay, and even the visible fertility that they leave behind them is almost uncanny.

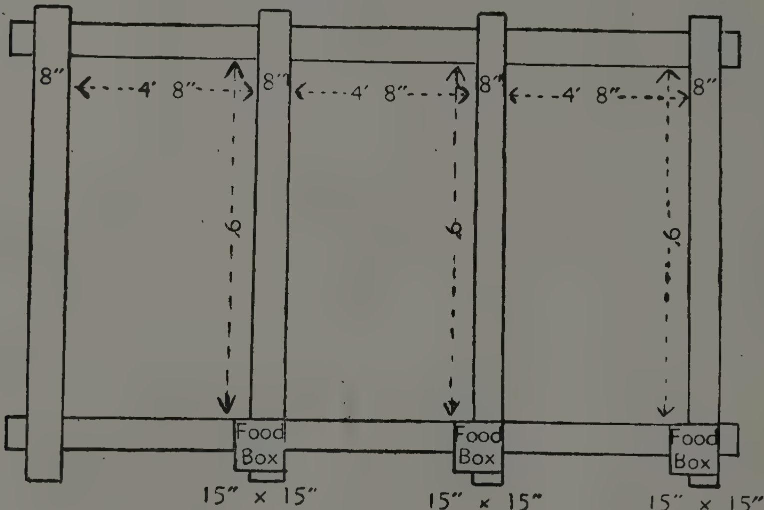
Every good farmer rotates not only his crops but also his arable and pasture land. By this means fertile paddocks come under the plough in their turn, while land from which much of the goodness has been drained is put back to grass and the goodness returned by the cow. In this connexion it is essential that the size of the paddocks should be in relation to the size of the herd. Keep the paddocks as small as possible. Short grass and concentrated manuring are an invaluable asset to the land. Long, coarse grass and manure scattered over wide areas of the countryside are of no use to anyone or anything.

In short, the efficient organization of dairying and arable farming should consolidate itself in the phrase so admirably demonstrated at the recent Nakuru Show: "Make the cows grow the crops for you."

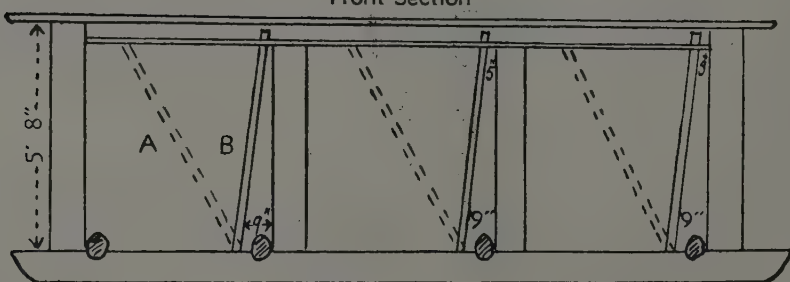
The dairy herd needs shade in its paddocks, but the plough cannot be expected to dart in and out of trees, scattered in clumps here and there, so build your shade *bomas* in the corners of your paddocks and not in the middle. These *bomas* will not then have to be uprooted when the pasture land comes under the plough.

DIAGRAM OF MOVABLE MILKING BAIL

Plan of the Base. Scale 12 in. = $\frac{1}{4}$ in.



Front Section

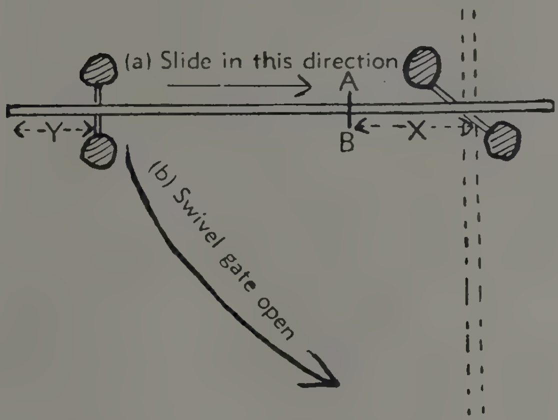


A ... Represents holding bar at rest.

B ... Holding bar in position.

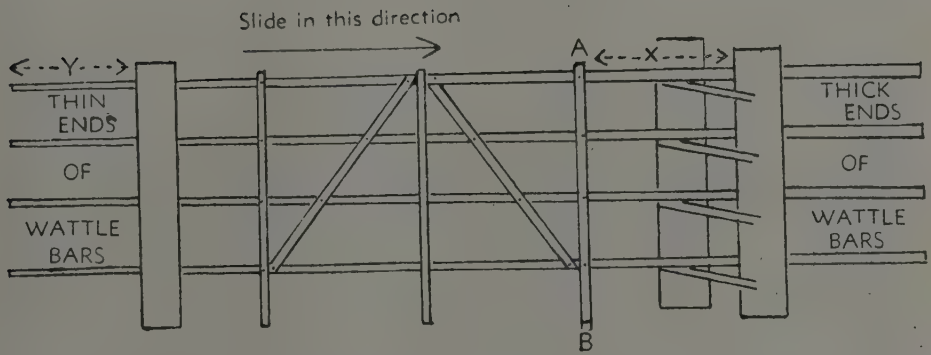
Fig. 1

METHOD OF GATE MAKING



(a) Length X must exceed length Y.

(b) To open the gate, lift and slide until line AB meets the supports on actual cedar posts, then simply swivel the gate open.



(a) Centre wattle supports must rest on ground.

(b) A nail must be driven through at every point of contact and turned over on the other side.

Fig. 2

Arable farming means labour lines. Labour lines, even with good latrines, inevitably mean measles infection, as it is very difficult to see that the labourers use them. So keep your dairy herd as far from native dwellings as possible. This applies particularly if steers are reared from the bull calves, or if the calves are reared for veal.

Perhaps the second most important point in the combination of arable and dairying is the actual control of the herd: the ability to keep the cows within their own bounds. It is indeed gratifying to find one morning that your recording shows an increase of ten gallons, but the gilt is very much removed from the gingerbread when you find after breakfast that this ten gallons has cost you half an acre of your best green maize. See that your fencing is sound and that your gates are proof against the herd "crasher," because every herd has one. A good formula, both effective and economical, for fencing is as follows: Seven-foot cedar posts, dug 2½ ft. into the ground, and 50 ft. apart. Five strands of wire, alternating oval and barbed, starting with oval at the top (to minimize the danger in the case of a cow trying to jump the fence) and placed at intervals of 3 in., 9 in., 9 in., 9 in., 10 in., and 14 in., beginning from the top. Four stout wattle switches to act as droppers in each interval of 50 ft. between the posts.

Gates are and always have been quite one of the most pressing of the minor problems facing the Kenya farmer. The whole question has probably aroused more weird and intricate solutions than any other. I make no apology for adding yet another, which originates, I believe, in Scotland. It seems to combine all the qualities of simplicity, cheapness and "boy-proofness". I have never yet seen it in print, but even if it has already been demonstrated doubtless many who have not yet seen it may read of it in this article. The materials required are sixteen 4 in. nails, twenty 6 in. nails, five straight, slim wattle sticks, which must be green, and four 7-foot cedar posts. It works on the swing principle. The attached diagram (Fig. 2) is probably more lucid than any elaborate explanations.

So far the assistance rendered by the dairy herd to the crops has been the main point of discussion. The crops themselves must in their turn render assistance to the dairy herd. Obviously the arable land must be made to grow the feed for the cows and for the benefit of the herd generally. On most farms in this country it should be possible to grow a sufficient variety of crops to enable the composition of a satisfactory balanced ration, with a little careful study of the protein, carbohydrate and bulk properties of each.

Linseed, a particularly valuable protein and laxative for calves when fed in the form of meal, can serve very well as a rotation crop. It should only be grown, on any particular field, say once in five years, as it makes very heavy demands on the soil. Vetch, peas, kale or carrots can also be effectively used in this capacity. These latter can also be used as "strip crops" between different types of wheat, which it may be found desirable to plant in one large field. It is obvious that these strip crops must be planted at least a month before the wheat to be effective in preventing one seed from washing into the next. Napier grass is an invaluable feed for cattle in times of drought, and a certain acreage should always be kept as a matter of routine. It can be used as a partial stop-wash, for which purpose it should be planted at intervals of one foot. The roots spread out and form an excellent barrier. It should be cut and fed during the dry weather and cut completely down to the ground before the beginning of the rains.

It has such a rapid growth that this should not affect its function of stop-wash in any way whatsoever. Constant cutting keeps the stalks and leaves fine and palatable to the cattle. If it is allowed to go on growing without any attention it becomes coarse and woody, too tall, and useless as a feed.

The Feeding of the Dairy Herd

Perhaps this would not be an inopportune time to give a few facts about the general feeding of the herd. We have made a number of experiments on this farm and the following formulæ have been found to be very effective.

Calves

First Week.—Three feeds per day, consisting of ¼ gallon of the dam's milk in each feed, a.m., noon and p.m. Exceptionally large or promising calves can be given up to one gallon daily.

Second and Third Weeks.—Half gallon whole milk a.m.; half gallon whole milk p.m.

Fourth Week.—Quarter gallon whole milk, quarter gallon skim milk, a.m. and p.m. To each feed add ¼ pint linseed meal. Linseed meal is made by adding four parts of water to one part of ground linseed. The mixture is placed in a petrol tin, which in its turn is placed in a receptacle of boiling water with a fire under it. It is allowed to scald for twelve hours before feeding, and this ensures that the meal is in an easily digestible state.

Fifth, Sixth and Seventh Weeks.—Feed as above, only add half a pint of linseed meal, and gradually increase the milk up to one quart of whole mixed with one half gallon of skim in each feed.

Eighth to Twentieth Weeks.—One gallon of skim milk a.m. and p.m., mixed with one pint of linseed meal.

From the eighth week onwards feed up to one pound of concentrates to each calf immediately after the milk.

It has been noted that the addition of two drops of tincture of iodine in the morning milk on alternate days has a markedly beneficial effect on the growth and general health of the calf. Those which have been given iodine have definitely done better than the others.

After the twentieth week gradually wean the calf by cutting down the milk. Some calves are easily taken off milk, while others lose condition. To the latter it may be necessary to give milk up to seven months and even older. While cutting down the milk, increase the concentrates slightly until the calf is over six months old, then gradually cut these down as well.

Always ensure that all calves have a plentiful supply of hay. Up to one month old the calves are kept permanently in their pens, but after that date they are allowed to run out for an hour after the morning feed and for another hour before the evening feed. After six months they are let out altogether.

After seven months they are moved to the heifer herd, where they will receive no artificial feed but they are always assured of a plentiful supply of good grazing and hay.

At nineteen months (or older, depending on condition) they are transferred to the milking herd until they come on heat and are served by the bull. When they are safely in-calf they are sent to the dry herd, where again they will receive no artificial feeding until they are within two months of calving. They are next moved into a paddock close to the milking bails, where they can be fed daily and a watchful eye kept on their condition. The amount of concentrates which should be fed to them during this period depends entirely on their condition. Many are almost too fat, while others require heavy feeding to ensure of their being in perfect condition when calving. Care

must be taken with the rations of the in-calf cows. They should not be given anything in the least likely to upset their digestions. In the last week before calving it is a good idea to give them a bran mash each evening.

In feeding the milking cows, a good general principle is that they are expected to give one gallon of milk daily without extra feeding.[1] After the first gallon, feed at the rate of 3 lb. concentrates per day for every additional gallon. It is impossible to be dogmatic on this point because the very important factor of the cow's condition has to be taken into consideration; it is intended merely as a working basis. The cost of one pound of concentrates, as suggested in the tables below, is approximately 4 cents. Some cows react readily to an increase in food, while some pay very poor dividends. It is therefore up to the dairyman to decide where the line comes between economy and pampering.

Bulls can be fed from 6 to 20 lb. concentrates per day, according to whether they are full grown or still growing and upon how much work they are called upon to do. They should be allowed as much exercise as possible, should be handled constantly, and should be given at least four hours of grazing daily, led about on a rope. This should ensure their being in a good temper and will give them plenty of green feed. There is nothing any animal dislikes so much as being confined in a small space. Oat hay should be fed every evening if it is available.

Salt-licks.—There are so many formulæ for salt-licks on the market that no useful purpose can be served by expounding at length on them, but the value of cobalt nitrate has been conclusively proved in certain areas. It should be mixed in the lick at the rate of 2 to 4 oz. to every 150 lb.

The above suggestions are not meant to be taken too literally, as every member of the dairy herd has its own peculiar characteristics. Some cows will refuse to eat concentrates under any circumstances, while others will make it their life-long ambition to steal as much of their companions' food as the watchful eye of the dairyman will allow them. It is hoped that the figures mentioned will serve as a basis on which to work.

APPENDIX

The following formulæ are worked out from foodstuffs easily grown or easily procurable in Kenya:—

For general purposes through the whole dairy herd

A

47½ per cent kibbled maize,
12½ per cent kibbled wheat or barley,
20 per cent linseed, crushed, or simsim cake,
10 per cent bran,
10 per cent molasses.

B

37½ per cent kibbled maize,
12½ per cent kibbled barley,
10 per cent linseed cake,
20 per cent simsim cake,
10 per cent bran,
10 per cent molasses.

For the milking cows and bulls only

22½ per cent kibbled maize,
22½ per cent cotton seed,
22½ per cent rice dust,
22½ per cent bran,
10 per cent molasses.

This gives a starch to protein ration of about five to one.

For in-calf cows and calves

65 per cent kibbled maize,
25 per cent bran,
10 per cent molasses.

It is essential to add bone-meal at the rate of 4 per cent to all the above formulæ.

Note on the Feeding of Cotton Seed.—Cotton seed is of great protein value. It can be fed to the dairy herd up to a maximum of 4 lb per day, but it is essential to soak it in water for twelve hours before feeding. If the cows do not take to it readily it can be mixed with their concentrates at feeding time. It is definitely not suitable for calves, and should not under any circumstances be fed to them. It is also inadvisable to feed it to the in-calf cows.

[1] On moderate to good grazing.—*Ed.*

Settled Holdings in the Tropics: A Comparative Review

By N. R. FUGGLES-COUCHMAN, *B.Sc., (Lond.), C.D.A. (Cantab.), A.I.C.T.A., Agricultural Officer, Department of Agriculture, Tanganyika Territory*

The introduction of mixed farming to the native communities of Africa has of recent years become an important feature of colonial agricultural policy. At the same time it has sometimes been combined with a settlement scheme, with a view to outlawing shifting cultivation and to introducing to the native settler the various improved agricultural practices that have been tested and proved by experiment. The ultimate aim is to raise the standard of farming and thus the standard of living amongst native tribes, while at the same time preserving the fertility of the soil. Therefore any experiment designed to investigate methods by which that object may be achieved deserves the attention of all those in whose hands lies the direction of native agricultural effort.

In a recent article[1] Professor Wood describes a fertility experiment on the farm of the Imperial College of Tropical Agriculture in Trinidad, on the results of which he bases certain conclusions with regard to the possibilities, economics and difficulties of settling peasants on small-holdings in a tropical country. It was desired to inquire into the possibility of maintaining soil fertility under conditions, such as those in parts of Africa, which preclude the keeping of cattle and require that every operation of husbandry be performed by hand labour. In the absence of stock, fertility was to be maintained by green-manuring, and in the rotation followed in the demonstration two of the four courses were green-manured each year. Because of the favourable climate of Trinidad it was frequently possible to green-manure each of the four courses in the year. Legumes such as soy-bean, pigeon-pea and cowpeas, grown for grain, also assisted in maintaining fertility. The rotation included two crops of maize, one early and one late, one of sweet potatoes and one of legumes, interplanted with cotton or tobacco, most generally the latter, which was looked upon as the cash crop. It was concluded that fertility, while not having been reduced, had not been increased by green-manuring, but the yields from year to year vary so much that it is difficult to obtain a satisfactory view of possible fertility changes. It is probable, however, that under conditions in Trinidad fertility could be maintained by a system of green-manuring combined with rotation of crops.

On the soils on the Morogoro Experimental Farm green-manuring with sunn hemp is at present the surest way of increasing crops of maize; the soils do not respond well to kraal manure and composts unless lime is added. The application of this knowledge to native agriculture in coastal districts where natives have unlimited land at their disposal presents problems, since these natives will look askance at methods aimed at increasing yields per acre when such methods entail the extra labour of turning in green-manure. Land settlement based on green-manuring, as described by Prof. Wood, could only be applied at present in areas with the right type of native and where pressure on the land exists. On the Kingolwira Settlement Scheme the peasants eventually will keep cattle to maintain soil fertility, directly by applying manure

[1] "Settled Holdings in the Tropics," R. Cecil Wood, *Trop. Agric.*, Vol. 15 (No. 7), pp. 147–153, 1938.

and indirectly by using animal power to turn in green-manures.

Climate is an important limiting factor in green-manuring. With a well-distributed rainfall, as in Trinidad, the work of planting and turning under green-manures can be spaced out. The soil is more frequently in such a condition that the work of digging under the green-manure is comparatively easy. At Kingolwira and in many other parts of Tanganyika Territory the uncertainty of the early rainfall would make it impossible to rely on green-manuring as the sole method of maintaining soil fertility. It would be desirable to green-manure the fields going down to maize or sorghum, but both these crops are essentially early sown under native conditions and frequently there is only a short period of rainfall during which the native can plant them; these times would coincide with the periods when the soil was soft enough to dig under the green-manure, supposing that the earlier rains had enabled a crop to be grown. Thus there would be a serious clash of cultural operations, nearly impossible to surmount when all work is done by hand. Prof. Wood allows eighteen man-days per acre for digging under the green-manure. Local natives, if they ridged over their green-manure, could possibly do it in fourteen days, but by that time the optimum planting period might have passed. The use of cattle makes the work possible, always providing that the early rainfall has been sufficient to grow a green-manure crop.

Prof. Wood stresses that every encouragement should be given to the keeping of cattle where conditions permit, and considers it would be wise in some cases to make the possession of cattle a necessary condition for the settler to obtain his land. This would be impossible in tsetse-fly and tick-infested country, as in the Eastern Province, except under a system of organized and controlled settlement such as at Kingolwira. There the purchase of cattle by settlers, once fly has been reduced, is a condition of their settlement. A herd has been introduced and is being maintained to supply cattle to the settlers.

From the yields obtained and from the nutritional value of the various crops grown, Prof. Wood estimates that under the conditions of the experiment a man, his wife and three children could obtain sufficient food and some cash from three and a half acres of land. In considering this figure it must be kept in mind that Trinidad conditions give two very certain planting seasons; thus two crops of maize can be grown and full crops of legumes and cotton or tobacco can be obtained from one acre. Under Kingolwira conditions the three and a half acres must be expanded to five and a half acres because, generally speaking, only small yields of such catch-crops as cowpeas or early maize can be obtained during the small rains from fields used in the main planting season.

Further, and here is *the* fundamental difference between land settlement as envisaged by Prof. Wood and as practised at Kingolwira, under the Trinidad system the settler would rely for the greater part of his income on being able to hire out his labour. The Trinidad settler is not to be a whole-time farmer; but it is expected that the peasant settled at Kingolwira will be fully occupied on his holding and should produce all the requirements of both food and cash for his family. A minimum holding considered adequate at Kingolwira is ten acres of arable with four to seven acres of grazing for cattle. No provision is made for feeding cattle in the Trinidad holding of three and a half acres, except indirectly in the form

of maize stover, the residues of leguminous crops, etc., which would hardly be sufficient to keep a minimum requirement of two beasts. It will be realized, therefore, that under the conditions of the Eastern Province of Tanganyika Territory and under the present land settlement policy, a holding as small as three and a half acres would be quite inadequate. Except in settled areas close to sisal or other estates, labour could not be sold readily except at the expense of the holding. Prof. Wood's figures and his system of working a smallholding are of interest, however, for an estate settling its own labour, when the labourer is in receipt of wages and food for himself. In view of the cash wages, the family unit need only produce food for the wife and children, and not necessarily for the whole year. From the figures quoted by Prof. Wood, to produce the total calorific requirements for a wife and three children some two and a half acres would be required under local conditions without green-manuring. Many estates could not afford to give up so much land, but intensive methods could reduce that area considerably, and in view of the fact that there is no necessity to produce the total food requirements one to one and a half acres farmed intensively should be sufficient. It would be no hardship for such a family to work intensively a holding of that size, thereby producing at least a good part of the necessary food, and such items as fruit and vegetables.

As a matter of convenience the whole of the Trinidad experiment was worked with cattle, but it was planned with a view to obtaining information to be applied in areas where cattle could not be maintained. As a result, in analysing the economics of and labour expended on the holding the author has had to estimate the man-days that might be required to perform all the operations. It is estimated that the total labour which would have been expended by hand operations would have been 319 man-days on three and a half acres. Prof. Wood does not state the number of hours to a man-day, but it is felt that with peasants working on their own, 319 days would increase to a considerably larger number which, with allowances for illness, collecting firewood and other minor occupations, would seriously cut down the number of days available for hire, on which the cash return is largely dependent. It is interesting to compare some of the estimated requirements of labour for one or two main crops in the experiment with actual figures from Kingolwira holdings. Thus, in Trinidad fifty days are considered sufficient for green-manuring and growing and harvesting a crop of maize; a native at Kingolwira, working by hand at his own pace, used thirty-one man-days for an acre of maize and twenty for sorghum. These figures are based on an eight-hour day, but very few natives work for that period on end, and the actual number of days occupied was greater than the number quoted. As a comparison, in supervised timing acres on an eight-hour-day basis, maize and sorghum crops were grown and harvested in twenty-five days.

Prof. Wood concludes with a reference to administrative problems and expense. A preliminary manuring given to the holding by the settlement authority is envisaged, besides assistance with green-manure seeds and in obtaining good live stock where that can be kept. He expresses the view that some sort of central communal store for the settlers' foodstuffs is strongly indicated. It has been found necessary to assist settlers at Kingolwira during the first nine months with foodstuffs and to build a hut, because the naturally improvident native arrives with

insufficient supplies. One or two acres of land are also partially cleared from bush to enable the settler to go ahead with planting his first crops. The need for a preliminary manuring of the land has hardly arisen as the area being settled is virgin land and in most cases can carry good crops from the beginning. It must be stressed, however, that the scheme at Kingolwira is at present wholly an experiment and it was necessary to render conditions as attractive as possible. At a later date, when natives come to settle in larger numbers, as it is hoped, any assistance given will have to take the form of a loan by the native authorities, and natives would be expected to act as they now do when they move from one area to another and be more self-reliant.

The provision of communal food-storage, while it might be an ideal, seems to present almost insuperable difficulties and administrative objections, at least in East Africa. Natives have evolved fairly satisfactory methods of their own for storing grain crops for long periods, and the more desirable course would appear to be small improvements in such local practices. The native is a suspicious fellow and would not look on a communal scheme with favour. But perhaps the greatest objection is an administrative one; in a big settlement Government would have to lay out large sums in the provision of storage facilities, in fumigation and in supervision, besides having to accept responsibility for any losses which might occur. It is felt that the aim of all settlement schemes for natives in the tropics should be to place both the individual and the settlement on a self-reliant and self-supporting basis, with ultimately a minimum of control and interference from the settlement authority.[1]

To summarize, while the experiment indicates that under certain very special conditions land settlement could take place on a holding as small as three and a half acres in which fertility could be maintained by green-manuring, it is considered that such a type of settlement, at least in the Eastern Province of the Territory and probably for most of the Territory, would not be feasible. It is desirable that a large proportion of the Territory's population should be able to support itself wholly on its own land, and in order that the standard of living should improve this must be based on a larger holding than three and a half acres. The aim of the Kingolwira and other settlement schemes is to produce good native farmers, versed in mixed farming, settled in their cultivation, progressing in their standards of living and largely independent of outside work for their income.

[1] In this connexion reference may be made to the recent description of communal grain stores in Nyasaland (this Journal, Vol. 4 (4), pp. 265-267, January, 1939).—Ed.

Notes on Feeds and Feeding

By R. S. Ball, *M.A. (Cantab.), Dip. Agric. (Cantab.), A.I.C.T.A., Agricultural Officer, Department of Agriculture, Kenya Colony*

The effects of a long drought have emphasized again the importance of the adoption of a breeding policy that will not outpace the ability to provide for the animals; that is to say, not to breed more highly than it is possible to feed economically within the limitations of the individual farm.

With the onset of the rains, however, opportunity occurs to make good the more obvious deficiencies in last year's feed supplies and to review the position for the coming year. Since veldt grazing is the feed most generally available to the farmer, the conservation of veldt grass is a matter of some considerable importance, and in this connexion the work done by Mr. J. D. Scott of the Estcourt Pasture Research Station in Natal is of interest. The process evolved by him was recently seen by the writer, and is of undoubted great practical value to the Kenya farmer.

The veldt grass should be cut in an immature stage before it is into full flower, and it is left in the swath until it has wilted, after which it is raked into windrows and cocked immediately, being then taken straight away to a baler and baled. The grass is not dried in the swathe but simply allowed to wilt; the amount of time allowed for this process depending on the degree of maturity of the grass and the heat of the sun. It is essential to note, however, that the grass is only allowed to wilt in this stage. The grass should not be baled too tightly, otherwise it is liable to become mouldy, nor should it be baled too loosely, otherwise the bales will fall to pieces on drying. When the bales have been made they should be stacked with air spaces all round them. The bales should be stacked in the open or under a roof with open sides for the first few days, so as to allow a free circulation of air, after which they can be stored in a more enclosed space if necessary. Excellent samples of hay were made in this manner with a minimum of wastage. It is considered that this method is well worth trial for Kenya conditions. It is, however, unsuitable for making other types of hay from crops grown on arable land, such as oats, vetches, etc., since they would inevitably become mouldy if this process were used. With adequate reserves of good quality veldt hay, the farmer is a least assured of a supply of roughages for adverse periods.

In many cases, however, cutting of the veldt is not a practicable proposition on account of the presence of bush, and conservation of fodder from the arable land is a matter of considerable importance. After the prolonged drought recently experienced it was not surprising that supplies of green Napier fodder became exhausted. It was noted, however, at Njoro that where the crop had been planted in rows wide apart it remained green for a considerably longer period during the drought, and experiments are therefore being laid down on the cultivation of this crop in rows six feet apart, sufficiently wide for a plough to work in between, so that a soil mulch can be maintained on the land and the period of availability of grazing increased during a dry period. It was interesting to note that the yield of milk of the dairy herd at Njoro was increased 12 per cent at the end of the dry season by grazing on Napier grass, little more than six inches high and beginning to dry off, for half an hour daily. This was in spite of the fact that the cows were receiving throughout a full ration

of 25 lb. of silage, together with 10 lb. of vetch hay daily. As a drought-resistant fodder grass, however, Pampas grass (*Gynerium argenteum*) proved outstanding, and it is only its slow rate of growth compared with Napier grass which discourages its more widespread use.

As a cheap, bulky concentrated feed, corn-on-the-cob meal has again proved its value, and although the feeding value of the cob itself is admittedly low, yet its presence undoubtedly renders the maize itself more palatable to dairy animals.

A considerably increased amount of cotton seed has been used by farmers for feeding this year, and they express themselves generally satisfied, but it is desirable to stress the fact that it is not to be recommended for young calves or for milking cows when fed in excess of 4 lb. daily. Suitable rations for dairy animals, comprising these two feeds, are as follows:—

Higher yielding cows (*three gallons and over*).—1½ parts simsim cake; 1 part cotton seed; 1½ parts corn-on-the-cob meal. Parts by weight. Feed 3 lb. per gallon.

Cheaper rations for lower yielding animals. —2 parts cotton seed; 1½ parts corn-on-the-cob meal. Feed at the rate of 3 lb. per gallon over the first gallon.

With the possibility of locusts, farmers in the arable areas will consider sunflowers as a partial insurance against these pests. Not only is the seed of this crop generally saleable, but the head, when gristed, is a useful cattle feed, having a considerably higher feeding value than the maize cob. It can be fed alone without the addition of the seed, and the crop is therefore worthy of consideration. In addition, it could be ensiled if the normal silage crops were eaten.

Poultry Feeding. — A considerable amount of discussion has ranged in the past about the subject of feeding of skim milk and maize as a ration for laying birds instead of the balanced rations of mashes and grain more usually recommended. It is interesting to note that this maize and skim milk feeding is no longer recommended in South Africa, since it has been found that the birds draw too heavily on reserves of protein in their bodies, which tends to shorten the economic laying life and makes the selection of breeding stock a difficulty, and as a ration for rearing stock it has proved to be highly deficient. As balanced mashes have proved frequently in Kenya to be little more expensive than a ration of maize and skim milk, there is no doubt about the value of adherence to these orthodox methods of feeding.

It is interesting to note that it has been found also in South Africa that a high magnesium content in the lime fed in the mineral mixtures to poultry is highly deleterious and may cause deaths, due largely to kidney trouble. It is possible that some of the unexplained deaths in Kenya poultry flocks may be due to this cause, and if so the solution is to remove lime from the ration and to feed oystershell separately instead.

A considerable amount of discussion has ranged in the past about the portable system of poultry folding with units, one of the chief disadvantages of the system being that the birds are necessarily very confined and may tend to get too fat or adopt bad practices, such as feather-eating. Some farmers are therefore folding the birds in large wire runs, enclosed with wire netting six feet high, these being moved at intervals of about one month, and using portable houses for sleeping and laying accommodation, which are moved about within the runs. They claim that by the adoption of this method all the advantages of folding are obtained, since the monthly move ensures that the birds are on fresh ground, while the effects of excessively restricted confinement are not felt.

The Gede Native Settlement Scheme, Kenya

By NORMAN HUMPHREY, *Agricultural Officer, Department of Agriculture, Kenya Colony*

Kilifi District, which includes the sub-district of Malindi, stretches from Mombasa District to the bush country south of the Tana River. A ten-mile belt along the coast forms part of the Protectorate, whilst further inland lies the Wanyika Reserve, but it is the coastal belt with which this article is concerned.

In this belt there is forest reserve in the neighbourhood of Mida. Nearer Malindi most of the land belongs to freeholders, as in other parts of the belt. These freeholders are mainly Arabs and Swahilis, though some freehold land is also owned by Europeans and Indians. There are also a number of leasehold estates, and finally there remain blocks of Crown land as yet unalienated. On much of the freehold land cultivation is also done by squatters. These are a legacy from the days of slavery, and the earlier squatters and their landlords had a definite understanding between them which seemed acceptable to both parties.

This was the general position prior to 1930, when the population was still very sparse. *Shambas* were worked on the shifting cultivation system, and owing to the low density of the population the resting period was long enough to allow a moderately heavy secondary bush growth to come up in abandoned *shambas*. Tsetse-fly was prevalent everywhere, with the result that stock was a negligible factor in the farming system. Under these conditions it is doubtful whether any soil deterioration was taking place.

The introduction of cotton, however, brought a new factor into the situation. This crop does well in the coastal belt, where it suffers less from climatic variations than further inland. The Wanyika soon realized this, and immigration into the coastal belt began. Before long many Wanyika were cultivating annual crops on Arab holdings; others began to squat on Crown land and follow their customary practice of clearing bush, taking two or three crops and then moving on to a new area.

It was soon clear, however, that there were dangers in such development proceeding uncontrolled. The balance of shifting cultivation must inevitably become upset with increasing population. The coastal soils are light sandy loams, which would rapidly deteriorate, especially if exposed to the full force of the monsoon winds, and much of the country might well be reduced to almost desert at no distant date if the movement and the farming system remained uncontrolled. Accordingly, steps were taken to devise a policy which would avoid the threatened dangers and allow development to take place on sound lines. In doing so a number of customs and other factors had to be taken into consideration:—

(*a*) Natives squatting on freehold land had hitherto not been permitted to establish permanent crops, or did so at the risk of being evicted by the landowner when the trees began to be of value. They had, in fact, no security of tenure, and consequently no inducement to take any care of the land they were using.

(*b*) Promiscuous squatting on Crown land was undesirable. Squatters had no right to the land and again could be relied upon to do nothing in the

way of soil conservation. The Wanyika will naturally spread themselves over an unlimited area if permitted, with consequent wastage of land. For both agricultural and administrative reasons this was highly undesirable.

(*c*) As noted above, tsetse-fly was prevalent everywhere and cattle were non-existent.

(*d*) Wind erosion was the immediate danger and exposure to the monsoon winds would also cause serious direct losses to crops.

(*e*) The question of water supplies would have to be considered in any proposals, as lack of adequate water has been one of the chief factors limiting development of the coastal belt.

The problem was first attacked by an approach to landowners. An effort was made to interest them in their land, especially the provision of windbreaks, which it was thought could be established without interfering with the tenure arrangements. Although willingness to co-operate was expressed, it cannot be said that any active interest was shown, nor was it possible to remove the distrust of tenants as to what would happen if they planted such trees as cashew nuts as windbreaks.

It was clear that a more definite scheme would be necessary to achieve results, and it might be hoped that success in such a scheme would induce others to adopt similar methods. A scheme was therefore put forward in 1937 under which it was proposed to deal first with squatters on Crown land between Kilifi and Malindi. Further immigration was to be stopped, but as regards those who were already there, two alternatives presented themselves: either they could be evicted and sent back to their reserve or they could be drawn into a settlement scheme, where they would be under control and would benefit by a certain security of tenure.

The second alternative was recommended, and it was proposed that a block of Crown land, containing some 10,000 acres, in the vicinity of Gede, should be set aside as a settlement. Suitable holdings were to be demarcated and settlers allowed in under permit, a start being made with people already squatting on Crown land. The permit gave security of tenure subject to certain conditions. The chief points were as follows:—

(*a*) In the event of the decease of the settler, no fragmentation of the holding would be permitted.

(*b*) Suitable methods of soil conservation would be laid down, and to these the settler must adhere or he could be evicted.

A detailed scheme on these lines was approved early in 1938 and a beginning was made in the long rains. A condition attached to the scheme was that a number of old but much smaller settlements in the coastal area should be brought into line with these proposals in due course.

It must be realized that the prospective settlers are mainly of a comparatively backward tribe, who have always practised shifting cultivation and have no reason to believe that any other system of cultivation is possible. Nor can the element of mistrust as to the motives of the scheme be ignored. To get true farming established with such people and under the peculiar conditions of the coast is a formidable task and it is well to realize this at the beginning of the scheme. For this reason the Gede area was chosen since the natives around there had shown themselves more receptive to propaganda than elsewhere and the relations between them and the officers chiefly concerned in developing the settlement

were sufficiently close to make them more amenable and more likely to have faith in Government's intentions. Nevertheless, the agricultural development of the holdings must be controlled carefully and the confidence of the settlers established not only in their security of tenure but in the methods of soil conservation which will be taught. Another difficulty to be faced is the necessity for starting the scheme with comparatively large numbers of settlers, as it is essential to include all squatters on Crown land as soon as holdings can be demarcated for them.

Whilst it is necessary to be quite clear as to how the holdings should be developed, it is equally necessary to have some flexibility in the programme which will allow for modifications from time to time in the light of experience. In this connexion the chief factor to be borne in mind is the possibility of creating a tsetse-free area and thus permitting cattle to be kept. Whilst there is reason to think, on the information available, that freedom from tsetse and the establishment of permanent crops are not incompatible, only experience can show whether this is true. To what extent efficient windbreaks may harbour tsetse is another point that requires elucidating.

Closely allied with the above is the probability that methods of rotation may be modified as time passes. A considerable amount of information on the value of resting crops has been obtained at the Experiment Station at Kibarani, but much more information is required and should be forthcoming later.

In these circumstances it has been decided that the average holding should be twelve acres. Of this, four acres would be devoted to permanent crops and the home compound, one acre would be planted with fodder crops, six acres would form the rotation for annual crops, and the remaining acre be provisionally allocated for trees. On present information trees, if given clean trunks, should be possible on the holding without fear of bringing in tsetse-fly. When cattle can be kept the rotational area should be capable of reduction by an acre, and this could then be put under trees and fodder crops instead.

Great importance is attached to the planting of permanent crops. Their presence undoubtedly helps to strengthen the feeling of security, whilst a judicious combination of these and annual crops should give the settler a much sounder basis for prosperity than can be obtained with annual crops alone. Further, the coastal belt is fortunate in the number of permanent crops suitable for cultivation there on peasant lines. Coco-nuts, kapok, cashew nuts and fruit for local consumption form a useful combination and these are being issued to settlers as soon as they start planting.

As has been stated, the first settlers entered in 1938, and it is expected that some 150 holdings will have been demarcated and given out before the long rains of 1939.

The importance of water supplies has been stressed. Certain supplies are already available, but more will be required if the scheme is to be fully developed. A hand boring machine was obtained in the last quarter of 1938, and at the time of writing the first two boreholes had both tapped water, though the quantity present and the potability of the water have not yet been properly ascertained. This boring machine is proving an inexpensive method of testing for water, and when adequate quantities are found a well can be dug, thus eliminating the expense of digging the wells haphazard. The present supplies need some minor works to improve them. A hydrographic surveyor is

visiting the area early in 1939 to go further into the whole question.

A demonstration holding is being established in the middle of the first area opened up and others will be developed as they appear necessary. Adjoining the demonstration holding an area has been set aside for social services. Here a market will be established in 1939 and here in due course the first school will be built and possibly a dispensary also. Settlers themselves will be expected to live on their holdings, and there is little reason to think they would prefer to live elsewhere. As they establish themselves and begin to reap some returns it may be hoped that they will themselves wish to live under better conditions and build themselves better houses.

Another very important aspect of the scheme will be the facilities it will provide for bulking improved varieties of crops. Such an area can be adequately supervised—an assistant agricultural officer is already stationed there—and this supervision is essential in the early stages of the issue of new varieties. In this way the work of the Experiment Station will be greatly strengthened and it may be expected that the spread of a new variety will be achieved with greater rapidity than is possible at the present time. This work was begun on a small scale in 1938 when seed issues were made to all settlers. The permanent crops issued were either new varieties or selected seed. Issues of the new food-crops were also made, but the full value of the system will only be obtained as the number of settlers increases. In the case of cotton, the settlement should afford the advantages of a segregated area, a need that will probably be felt at an early date.

In the above notes it is hoped that the general outlines of the Gede Settlement Scheme have been made clear. A start has been made, but it must be expected that numerous obstacles will be encountered as development proceeds. Such obstacles, however, will be more easily overcome than the dangers inherent in a policy of uncontrolled development, whilst the advantages of starting a scheme early before the need has become too urgent are immense. To achieve results will mean much patience; though hard work and disappointments are bound to occur, success in this undertaking will not be limited in its effects to the settlement alone, but will prove a powerful influence in improving native agriculture over a wide area.

The Effect of Treating Coffee with Different Micro-Florae: with General Notes on Coffee Liquoring Reports

By G. H. Gethin Jones, *M.Sc., Soil Chemist, Department of Agriculture, Kenya Colony*

A report of certain investigational work on the effects of certain coffee micro-flora on coffee quality, carried out by Senhor Rojerio de Camargo in Brazil and by Dr. C. Picado in Costa Rica,[1] suggested a direct line of approach into factors governing coffee quality in East Africa. These American workers showed that all coffee samples prepared by the wet method of pulping and drying the washed beans always gave a mild coffee, whereas similar coffee when prepared by the dry method of decorticating the dried cherry gave a harsh or Rio-flavoured coffee. Furthermore, they showed that when the pulp of a superior quality coffee was added to other fermenting pulped coffee, the resulting beverage was of a higher quality. It was considered that work of this nature should be carried out as a possible means of raising the general level of the quality of local coffees. Such work, which could be initiated in a simple manner, was believed to offer a greater chance of success than bio-chemical studies of the metabolism of coffee bushes and bean analyses, when one considers that analytical data need not necessarily explain the finer differences in the liquor of mild coffees. It was appreciated that in East Africa we have to deal with differences of liquor within a series of mild Arabica coffees, and also the elimination of taints and certain characteristic flavours which lower the market value of the samples.

A fairly elaborate scheme of field and laboratory work was arranged to test the effect of the dominant micro-flora obtained from varied coffee beans of known performance on the quality of other coffees. This was done by various methods, such as the adding of isolated specific yeast cultures to pulped beans, the spraying of sugary solutions of these cultures on to coffee cherries which were then allowed to dry into *mbuni*[2] coffee without heating, and again the spraying of these sugary culture solutions on to ripening cherries on the trees, which were later prepared both by the wet fermentation method and by the dry *mbuni* method. Five isolated pure cultures were used, including those obtained from two samples of coffee beans which were reputed to give a "foul" liquor. Sixty samples of coffee taken from six estates were prepared separately and given specific treatments. Each prepared sample was divded into two, thus giving a total of 120 samples for liquoring. Apart from different set treatments, all samples were prepared at the coffee factory in as uniform a manner as possible.

The first cultures were prepared by Dr. Case just previous to his departure. Coffee beans from selected parcels of coffee, each of which had been allotted a characteristic liquor by Mr. Devonshire, were used. A selection of the resultant cultures was then multiplied in batteries of Roux flasks and filtered to remove the medium from the

[1] "Recent Advances for the Improvement of Brazilian Coffee," *Monthly Bulletin of Agricultural Science and Practice* (28), XXVIII, pp. 13-21.

[2] *Mbuni* is prepared by drying the coffee cherry and subsequently hulling it without the processes of pulping and fermentation.—*Ed.*

yeast mass. The latter then was made into watery or sugary suspensions, according to their later use. About half a litre of a creamy yeast suspension was usually prepared.

Experimental Technique

A—Addition of Cultures to Pulped Coffee

Culture No. 5, prepared from a commercial sample of coffee described as "very good with fine acidity" was added to pulped coffee obtained from two estates which normally have coffee of a poor liquor. The treated samples of pulped coffee had a much more creamy and frothy type of fermentation. Examination of prepared slides of the final fermenting effluents of treated and control samples were compared with previously prepared slides of the culture used. The non-treated showed mainly clusters of bacteria, whereas the treated contained mainly yeast cells similar to those added. However, aliquot portions of the ferment and of the preserved sterilized yeast suspensions showed that the number of yeast cells had only about doubled in number after forty-eight hours' fermentation. Treatment produced no differences in the coffee liquor.

In the case of one estate, three groups of six trees were sampled separately in two pickings. In both cases the coffee from one group of trees gave a much slower fermentation than the other pair. In the liquoring report, there is as much variation between sub-samples as between treatments, and frequently one sub-sample is denoted as "sourish," whereas the other portion is not. As regards the visible factors of size and colour of the raw bean and the type and make of the roast, the liquoring reports are remarkably constant for similar pickings of coffee. Treatment did not result in any significant differences in liquor.

Culture No. 7, prepared from a commercial sample described as "very good," was similarly added to portions of freshly pulped coffee. The treated coffee had a characteristic fermentation, the organisms present at the end of fermentation being predominantly yeasts; whereas the control ferment showed mainly bacteria and very few yeasts. Slides of aliquot portions of the treated ferment and preserved sterilized yeast suspensions indicate that the yeast had multiplied about four to five times. The final pH of the treated effluent was 4.14, whereas that of the control was 3.38. The liquorer's report shows no result due to treatment.

Culture No. 9, prepared from a commercial sample described as "foul," was similarly used. In this case, though the culture-treated pulped coffee contained organisms in which the added material predominated, it was not possible to say that active growth of the added culture had taken place. In such a case any differences in liquor could not be associated with the added micro-flora. In fact, there was no reported difference in the liquor—all samples, both treated and control, were "tainted".

Culture No. 12 was prepared from a commercial sample of coffee which had been described as "unclean". The culture made slight increased growth in the fermenting effluent. Liquoring of eight sub-samples showed no effect of adding this "unclean" culture. Two control and one treated samples were allocated the term "slightly greenish," and another control was described as slightly fruity, and the remaining four, including one control, had no adverse qualifying remarks.

Culture No. 15, obtained from a sample of coffee described as "foul," was used in a similar manner with coffee from two sources. This culture made very slow growth in the Roux flasks and made no further growth in the fermenting coffee; therefore results of experiment were discarded. In fact, all samples liquored, both treated and untreated, were slightly to strongly tainted. The addition of varied yeast cultures to pulped coffee produced no differences in the liquor.

B—Spraying Sugary Culture Suspensions on to Coffee Cherries

Portions of the varied yeast suspension were given the addition of $2\frac{1}{2}$ per cent glucose, and the sugary solutions were sprayed on to numerous batches of cherries. The solution was given in two applications, the second about two hours after the excess liquid of the first application had dried off in the shade. After further slow shade drying, the cherries were then dried in the sun in a single layer with daily turning. The cherries continued to have a sugary coating for one to two weeks. The *mbuni* coffee was hulled when the contained beans were dry and hard.

A sugary solution of *Culture No.* 5, obtained from coffee reported as "very good with fine acidity," was sprayed on to four batches of cherry from two estates. Four samples of similar untreated cherries were used as controls. In the liquoring reports, all coffee prepared by the method of hulling the dried cherry was given an inferior report as compared to the same coffee prepared by the wet fermentation method. The liquor of both treated and untreated coffees was invariably reported upon as "sour," with no recorded values for the acidity, body and flavour of the liquor, as it was considered that the marked sourness made differentiation impossible. The value of the make of the roast is given as nil in all the sixteen sub-samples liquored. They were reported upon as typical *mbuni* coffees. The spraying of the yeast on to the cherry had no effect on liquor.

Culture No. 7, representing "good coffee," was similarly sprayed on to other samples of cherries. In this instance sprayed and control cherries were dried indoors for two days and then dried in the sun with daily turning. Again all samples, treated and untreated, were described as sour typical *mbuni* coffees.

Culture No. 9, representing "foul" coffee, gave similar results when a sugary suspension of the culture was sprayed on to coffee cherries. All samples are reported as sour *mbuni* coffee.

Culture No. 12, representing "unclean" coffee, was similarly used. In this instance the liquorer's reports gave "slightly fruity" to "sour". The remark "sour" was allocated to three treated sub-samples; "sourish" to two untreated and "slightly fruity" to the remaining two untreated and the one treated. Three of the four pairs of sub-samples have been given different reports. There was no result due to treatment.

Culture No. 15, representing "foul" coffee, was similarly applied, with no effect on resultant liquor. All samples were described as sour *mbuni* coffee.

C—The Spraying of Ripening Cherries on the Trees

In order to give selected yeasts a greater opportunity to exert their influence, a series of field trials was arranged whereby groups of trees carrying ripening cherries were sprayed with sugary solutions of selected yeast cultures. This gave the cultures a chance to develop as the local dominant micro-flora over a period of about ten days during the ripening of the cherry. In one instance initial pickings were taken from two groups of trees to be sprayed in order to obtain initial data about the liquor and to compare this with the liquor of the next picking, which had received a double spraying of a sugary culture solution. Another group of trees was not sprayed, so as to give the normal change, if any, in the liquor of the following picking.

Culture No. 5, prepared from a commercial sample of coffee described as "very good with fine acidity," was used in the major field trial of this series. A double application of culture spray was followed by sixty hours of fine weather before the advent of heavy rains over three days (totalling 2.48 inches), which in turn was followed by five days of fine warm weather before the ripened cherries were picked. Cherries from groups of sprayed and unsprayed trees were prepared by both the wet fermentation and the dry *mbuni* method. Coffee prepared by the wet fermentation method had a similar ferment for both sprayed and unsprayed coffee, the final pH values of two treated lots being 3.62 and 3.80 respectively, whereas the controls showed intermediate pH values of 3.74. The examination of prepared slides of the resulting ferment showed more large yeast cells for the sprayed cherries than for the unsprayed, but their presence may have been adventitious from the pulp during pulping. Sixteen samples were reported upon for liquor. There was no difference in the liquor of the treated samples; all were described as having a certain characteristic taint in varied degree, which taint was typical of the area that produced this coffee. These reports can be compared with those given for the previous pick of coffee from the same group of trees. There was a general variation in the visible quality factors for the two pickings. Every sample of the second picking was allotted slightly higher values for the "type" and "make" of the roast, and two groups of trees, including the one control group, were given appreciably higher values for the acidity and flavour.

Culture No. 7, representing "good coffee," was similarly used for spraying individual

selected trees, whereas other unsprayed trees were taken as controls. There was no result following spraying. This coffee was subjected to severe dieback, and tended to give many black and orange-yellow cherries, due to improper ripening. Ripe cherry was picked 16 days after spraying and owing to the mixed nature of the crop this was divided into three lots and then subdivided for liquoring. The ripe cherries were prepared by the wet fermentation method, the remainder were divided into "green cherries" and "black-orange-yellow" cherries and prepared by the dry *mbuni* method. This division gave interesting liquoring results. All four samples obtained from green cherries were given lower values for size and colour of bean and described as of "pale, immature appearance with an unclean, almost harsh, liquor." The coffee prepared from "black-orange-yellow"-coloured cherries with improper ripening was given relatively higher values for size and colour of the raw bean, and described as of "pale, immature appearance," though less so than the coffee obtained from green-coloured cherries. All four samples of the former type were described as having a "greenish" taint.

Summary of Results

An analysis of a total of 120 liquoring reports shows that, under the conditions of these trials, the addition of prepared cultures to pulped coffee and the spraying of sugary solutions of such cultures on to picked cherries and to ripening cherries on the trees has had no effect on the resultant liquor of the coffee. Twelve different treatments, using cultures prepared from good coffees and "foul" coffees, carried out on samples of coffee from different estates, were without result. Samples, both treated and untreated, of coffee obtained from certain areas known to have a peculiar local adverse characteristic liquor or taint were described as having that taint.

General Observations on Liquoring Reports

Although this work has given negative results in its main purpose of attempting to alter coffee liquor by introducing selected micro-flora, certain interesting observations can be drawn from the numerous liquoring reports. Almost all samples of coffee prepared by the dry *mbuni* method gave a "sourish to sour" liquor, whereas similar coffee prepared by the wet fermentation method gave varied characteristic liquors. The few sub-samples of *mbuni* coffee not described as "sour" were "unclean" or "fruity". Very careful *mbuni* preparation, involving the slow drying of the cherry with daily turning, failed to produce good quality mild coffee—a result differing from that obtained by Brazilian workers with Rio or harsh coffees.

As all treatments were at least duplicated and often had four replications, and moreover all prepared samples were further subdivided for liquoring, the final sub-samples served as a means of studying the uniformity of liquoring results. The various visible and invisible quality factors in parcels of similar coffee can best be studied separately.

Visible Factors

The value for size of the raw bean is remarkably uniform for coffee from one source if prepared by the same method. However, when preparation is different, as when some samples were prepared by the dry *mbuni* method, the size is again uniform, but invariably smaller.

The colour of the raw bean is similarly uniform, there being only a few exceptions, with a difference of a quarter of a point only. Similar coffee when prepared by the *mbuni* method has invariably been allocated uniformly lower values for colour. Again, the value for "type" of roasted coffee is uniform for the same coffee which has been similarly prepared. Similarly with the "make" of the roast, similar coffee was always allotted similar values; with this particular characteristic,

the value was invariably lower when the coffee was prepared by the dry *mbuni* method.

In one special case, when cherries were picked separately from three groups of six trees, the reports, though constant for each group of trees, show slight differences between groups of trees, and again for different pickings from the same group of trees. The three groups of six trees all produced a second picking which was allotted higher values for the "type" and "make" of the roasted coffee. It will be noted that with visible quality factors for the raw and roasted beans the liquorer's reports are remarkably uniform for similar parcels of coffee prepared by the same method.

Observations on the Invisible Factors in Liquor of Coffee Samples

As stated above, reports on the visible factors of similar parcels of coffee are remarkably uniform. However, this uniformity is often absent when dealing with coffee liquor and more especially when recording such quality remarks as "fruity," "greenish," or "tainted." Apart from any treatment factor, samples of the same coffee, similarly prepared by the fermentation method in two, three or four units and later duplicated for liquoring, often show differences in their liquor. Moreover, different cups of the same roast may be given different reports. These differences apply more particularly to the absence or presence of adverse properties, such as "fruity," or "tainted." An analysis of the liquorer's reports of four-ounce sub-samples of numerous batches of coffee enables one to study the degree of variation that obtains. In the absence of certain adverse qualifying remarks, the values allocated for acidity, body and flavour are usually within half a point for most samples, and in many cases identical values have been given. When certain samples are "very slightly tainted" to "tainted," the differences for sub-samples are usually greater, and these differences are still more pronounced when some of the sub-samples are described as "slightly fruity." The differences are greatest when some of the sub-samples are described as "sourish."

When ripe coffee is prepared by the *mbuni* method, it is described as "sourish to sour" in 45 samples out of 52, and is characterized as typical *mbuni* coffee. Of the remaining seven samples, four in one batch of twelve are described as "tainted" and three in another batch of eight are described as "slightly fruity." These differences show no relationship to treatment but often cut across a series of sub-samples. In six remaining batches of *mbuni*-prepared coffee, all 32 samples are described as "sour." Thus in the above-mentioned two batches with differences, the sub-samples which are not described as "sour" are without exception described either as "tainted" or "slightly fruity," thus suggesting some relationship between these properties and sourness. Four samples of green cherry prepared by the *mbuni* method were all described as "unclean, almost harsh," and another four samples of black-orange-yellow cherries from the same trees were all described as "pales" in the roast and "greenish" in their liquor.

The difference in the liquor of the coffee samples prepared by the normal wet fermentation method may arise from two causes, or from a combination of these two: either there are intrinsic differences in the composition of the sub-samples—usually four-ounce units—or else the personal equation of the liquorer is responsible. In the case of inherent differences in the general composition or summation of all the individual beans present in the sub-samples presented for

report, this must be due to the chance presence of a very few coffee beans that exert an undue influence on the liquor. The fact that different cups of the same roast can be different strengthens this assumption that very few beans of unsuitable liquor can influence and lower the quality of the whole sample. On the other hand, the personal equation of the liquorer may be responsible for different reports on sub-samples which have been re-arranged for liquoring purposes, more especially if the samples are distributed in mixed batches of coffee and liquored at different times. Should the personal equation be pronounced, then it becomes necessary to standardize the liquorer; that is, to find out the minimum number of replicate samples required for "uniform" liquoring.

A study of the grouping and time of liquoring suggests that inherent differences in the make-up of the samples is the major cause of dissimilar reports, more especially in the reported presence of varied taints. Here again, failing the detection and removal of the inherent influencing factors, there is need for sufficient replication of sub-samples so as to eliminate this deleterious influence. In the commercial sampling of a consignment of several bags of coffee there is a great chance of variation according as to whether this small influencing factor is missed or whether it finds its way into the sample liquored in determining the value of the coffee. This sampling error may be partly responsible for the differences that obtain in the liquor of certain consignments of coffee which are again sampled and liquored abroad. It is apparent that there is need to standardize the uniformity of reports of all sets of coffee samples in all liquoring investigational work. In the past, single or at least too few samples have been submitted for report on coffees which represent specific treatments. There is need to submit the requisite number of replicate samples for each treatment so as to eliminate or rather to outweigh any disturbing influences. The immediate task is to find out whether it is possible to associate certain kinds of coffee beans and coffee treatment with the various adverse properties which it is believed that they assert on the whole sample. Work along these lines is now being undertaken. If it is found that a limited number of certain kinds of beans exert a great effect, and if these can be eliminated, then liquoring reports would be more uniform for a series of sub-samples and the necessary normal standardization of coffee samples for liquoring purposes could then be more easily worked out.

The writer wishes to acknowledge the essential services of Mr. Devonshire, liquorer to the Coffee Board of Kenya, without whose co-operation this investigation would not have been possible. Thanks are also due to those coffee planters on whose estates this work was done, and to Mr. A. M. Pratt, who had charge of all the factory work involved.

Comparative Trials at Mpwapwa with Leguminous Crops of Value in Feeding Live Stock

By M. H. French, *Ph.D., M.A., Dip. Agric., Chemist, and* H. Winship, *Senior Assistant Live Stock Officer, Veterinary Department, Tanganyika Territory*

Lack of digestible protein material characterizes the dry-season grazings not only of this Territory but of most of the tropical and sub-tropical regions of the world. In the Annual Reports of this Department for the last five years this fact has been stressed, and it has been pointed out that not only the native-owned stock, but in many instances European-owned stock also, suffer from a gross shortage of nitrogenous matter in their diets.

Because of the marked symptoms of ill-health and disease that are encountered in the stock of certain areas, these districts are recognized as mineral deficient. In other areas an absolute shortage of grazing may become so acute that its presence is manifested in the stunting and emaciation of the stock, and even by death owing to starvation. Protein deficiency is even more widespread than either of these, but because its symptoms are not so apparent and its consequences are not so drastic its presence is often disregarded or unnoticed. Shortage of protein in the diet of stock causes a retardation of the growth rate, diminishes milk yields, lowers the rate of reproduction, and, because it prevents the proper development of body tissues, predisposes towards infections and disease.

The future of native husbandry practices in the tropics is bound up with the provision of cheap, easily-grown nitrogenous foodstuffs in amounts adequate to meet the demands of all classes of stock. It is even more important for those farmers who are attempting to grade up an improved type of animal that the growing of protein foodstuffs should figure largely in their plans. The breeding of high-yielding milk cows is absolutely impossible without enough protein in the diet.

The low protein content of the majority of the dry-season grazings can be supplemented by the purchase and feeding of the residues from oil mills. The majority of farmers, however, are very reluctant to spend money off their farm, and for them the best method of ensuring a sufficiency of protein foodstuffs is to grow legumes. For the native husbandman this is probably the only method available.

Leguminous seeds can be fed in the concentrate part of the ration, whilst legume hays form a highly palatable and very nutritious protein feed. Such leguminous crops enable the farmer to improve his stock and at the same time to enrich the fertility of his land.

The majority of farmers will prefer to make hay rather than to go to the expense of picking the pods and threshing out the seeds. For hay the crop should be cut before the seeds are ripe, but after the pods are well developed. A certain amount of care is necessary if good hay is to be made, because the leaves dry more quickly than the stems. Good weather is almost an essential if good hay is to result, because the crop must not be turned and moved about more than is necessary. The dried leaves shatter very easily, and due caution must be exercised to reduce this leaf loss to a minimum whilst making sure that the stems are correctly dried.

Several methods of making cowpea hay have been tried by one of us (H.W.),

FIG. 1

A small legume hay stack showing triangular trestle in position and the bag being drawn up to form the central air-chute

and the best for our local conditions is as follows. When a reaper is not available or cannot be used because of ridges, the plants are cut off near the soil with a hoe and about ten plants are rolled loosely together. These bundles are turned daily until the leaves, but not the stems and pods, are dry. In this condition the bundles can be lifted easily with a hay fork without much loss of leaf. After carting, the crop is stacked on a base 4 yards square. On the windward side of the square base a triangular trestle with sides 3 ft. 6 in. long is so placed as to make a tunnel or air-chute leading into the centre of the stacked hay. The two upper sides of the trestle are covered with wire-netting or lattice-work so that hay can rest on them. Up the centre of the stack a vertical air-chute is made by placing a sack of hay immediately above the central end of the trestle. The crop is then stacked in the ordinary way, but as the stack gets higher the bag of hay is gradually drawn up so that a central chimney is formed. By this means air can circulate through the stacked legume crop and overheating is prevented, but the stems are allowed to dry out properly (see Fig. 1). Good legume hay is relished by all classes of stock and is particularly valuable for calves, milking cows and horses.

So urgent is the need for more and for cheap protein foodstuffs in the drier areas

of this Territory, and so imperative is it that only the most economical legumes should be cultivated, that it was decided to intitiate a series of experiments at Mpwapwa to discover which legumes should be encouraged. For this purpose a number of acre plots were marked out on a field which had been ridged along the contours to minimize erosion. On each plot a different legume was to be sown, one-half of the crop to be converted into hay and the other to provide seed. It was originally planned that the experiment should last five years, but since the majority of the crops tried have not done sufficiently well to justify further work the results of the first three years will be summarized below.

Mpwapwa is situated at an altitude of a little over 3,000 feet, and the soil of the district consists of a red-brown sandy loam. The area occupied by the Government Farm was abandoned by local native cultivators after they had exhausted the soil by continuously cropping without manuring. The soil has since been improved but is still deficient in humus. The average rainfall is about 25 inches and is spread over a period of four or five months, whilst the rest of the year is almost completely devoid of rain. The growing season is therefore confined to the rainy season and then the land lies fallow until the next wet season. The Mpwapwa conditions are thus typical of much of the Central Province and are also representative of a large proportion of the Central Plateau area of the Territory.

The results to date are so clear-cut that the experiment will now change to one comparing only the most suitable crops for our dry conditions, with some further observations on the value of these legumes for silage production. Experiments have been made, and are reported upon in the 1937 Annual Report of the Veterinary Department, comparing the feeding values of the different hays.

The field chosen for this experiment had grown maize and cowpeas in rotation for several years previously and received in 1932 a dressing of kraal manure at the rate of six tons per acre. The cultivation prior to the planting of the crops consisted of ploughing, light harrowing, and then ridging along the line of the contours. The crops were then planted along the ridges by natives using their own native method.

In the first season germination was good on all plots and the plants grew well for about four weeks. After this interval it was noticed that whereas the crops of velvet beans, soya beans, dolichos beans and cowpeas continued to do well, the *maharage* beans (a form of *Phaseolus vulgaris* L.) and field peas began to go yellow and numbers of plants died off. About the fifth week a dry interval occurred in the rains, and as a result large numbers of these two crops wilted and died. These two plots took on a very depressing appearance, with only a few scattered plants struggling to exist, in marked contrast with the healthy-looking crops surrounding them.

The dolichos and velvet beans made long runners, and together with the cowpeas were ready for hay ten weeks after planting, i.e. they then were still in flower but a number of pods were well formed but not ripe. The hay was made in anything but ideal weather and as a result the quality of the product suffered, because many of the leaves shattered and fell off before the stems and pods were sufficiently dry for carting. It appeared that more leaves of the dolichos and velvet beans were lost than in the case of the cowpeas, and much trouble was experienced in getting the green succulent

pods of velvet bean to dry out quickly. The plants of these three crops had reached a height of about two feet at the time of cutting for hay. The seeds were collected at intervals during the following two months because all the plants did not mature at the same time.

The soya beans grew to a height of only ten inches, and were obviously unsuited for hay; as a result the whole of this plot was allowed to mature and the seed was collected. This crop died off much earlier than the velvet and dolichos beans and cowpeas, and this particular variety of soya was obviously unsuited to our soil and climate. However, since there are hundreds of varieties of this bean these results do not necessarily mean that other varieties would prove equally unprofitable.

Maharage beans are widely grown by the natives as a food crop. For this reason it was hoped that the haulms might prove a valuable addition to the dietary of native-owned animals. The plants in this plot suffered badly from the early drought and many died; the survivors never reached a height of more than ten inches. This crop was obviously unsuited to the making of hay, and the whole plot was used for seed production.

Peas were included in this series because of their value in certain parts of the Territory as a human foodstuff. As was expected, our hard conditions proved too much for them. Germination was not good and many plants died in the dry spell. A height of twelve inches was reached, but very few plants looked healthy, and only a small percentage yielded seeds. No attempt was made to make hay of this crop. So badly did it fare that it was removed from the experiment and not tried again in the last two years.

In addition to the above an acre plot of buckwheat was sown. This plant is gaining popularity in the Southern Highlands, and the opportunity of studying it under our dry conditions was welcomed. It proved unsuited for haymaking and the whole plot was used for seed production. The crop did not fare very well and a height of only fifteen inches was reached. One big drawback to buckwheat is that ripening is spread out over a long period and many collections are necessary, with the further disadvantage that many seeds are lost.

The experiment was repeated in the 1936-37 season with somewhat similar results. In this year the dry spell occurred earlier, and many young plants were killed in each plot, and a second sowing was necessary to fill up the gaps. The *maharage* and soya beans were again stunted and poor, and quite valueless as hay crops. The velvet and dolichos beans and the cowpeas again stood out as fodder crops and all made fairly good growth, but the first named was not quite so good as the other two. Half of each crop was turned into hay, and the seeds were collected from the other half. This year a terrible pest of insects attacked the plots and made devastating raids on the *maharage*, the cowpea, and particularly the dolichos plots. The insects concerned were kindly identified by the Entomologist of the Agricultural Department as *Halydocoris corticinus, Calidea dregei, Acanthomia tormentosicollis, Harpactor segmentarius, Alcides arcuatus,* and *Mylabris* sp. The buckwheat crop was again poor and a plot of serradella failed to germinate.

The third year of this investigation proved to be a very bad year. The total rainfall for the 1937-38 wet season was only 19.4 inches, and this was extremely badly distributed—over half the total

quantity fell in the second week of February. It was nearly the end of January before ploughing could be started (instead of at the beginning of December) and planting was delayed till the early part of February. The rates of seeding were the same as for the previous years, but *maharage* beans and buckwheat were not planted because of their failure in the first two seasons. Germination on all plots was very good indeed and the plants started off well. However, the poor rains in early March caused a number of plants on all the plots to die off and retarded the development of the survivors. This setback was immediately followed by an even more devastating insect attack than occurred the previous year. The dolichos bean and the cowpea crops were completely eaten off. There were no cowpeas left to set seeds or to be converted into hay. On the dolichos bean plot, however, a number of plants sent up new shoots which were able to seed. The velvet beans were not eaten by the insects but about 25 per cent of the crop died as a result of the drought. This year the whole of the velvet bean crop was allowed to set seeds and the seed only was harvested.

The results obtained in the last three seasons are summarized in the table.

In the second season, pigeon peas were planted on the plot that had originally been planted with ordinary peas. No seeds were collected in the first season, but the plants grew well. It was hoped that a good crop of seeds would be reaped this last year, but the yield was extremely disappointing (14 lb. per acre), and so this crop must be considered unsuitable for areas of poor rainfall. The plants were not attacked by insects.

One interesting feature of this table is the low yields obtained from *maharage* beans. This legume is very widely cultivated by natives and the poor yields are surprising. Obviously this bean requires a better distributed and possibly higher rainfall than is normal for Mpwapwa.

The soya beans gave a promising yield of seed in the first season from soil which had not been inoculated with symbiotic bacteria. The more severe climatic conditions in the second year were responsible for the low yields then obtained. The particular variety planted must therefore be considered unsuitable for our conditions and, because of the high dietetic value of the beans for man, a more drought-resistant type should be sought.

YIELDS PER ACRE OF VARIOUS CROPS (IN LB.)

Crop	1935–6			1936–7			1937–8	
	Seed sown per acre	Seed yield	Hay yield	Seed sown per acre	Seed yield	Hay yield	Seed sown per acre	Seed yield
Velvet Beans	30	444	1,200	30	414	1,660	30	314
Dolichos Beans	30	186	1,238	28	50	1,960	30	19
Soya Beans	30	198	Not made	30	26	Not made	—	—
Maharage Beans	20	48	Not made	22	68	Not made	—	—
Cowpeas	30	38	2,430	25	510	2,080	30	Nil
Peas	35	17	Not made	—	—	—	—	—
Pigeon Peas	—	—	—	40	Nil	Nil	Nil	19
Buckwheat	40	118	Not made	35	58	Not made	—	—

The returns from peas, pigeon peas and buckwheat show that these crops are uneconomic in areas of uncertain rainfall.

The velvet beans gave consistent yields of seed in the first two seasons but a lower yield in the third year. This latter yield was, however, at the same rate per plant as in the previous years because about a quarter of the plants died in the drought. These beans were not planted with a supporting crop and the growth of the vines, and hence the yield of beans, was smaller than might otherwise have been obtained. When planted amongst maize this year a much heavier growth was obtained and a larger number of pods were grown on each plant.

The cowpeas in their second year gave a fairly good yield of seed in spite of insect attack, but in the first year the yield was very disappointing. This was probably due to climatic conditions, for in good years yields of up to 600 lb. of seed per acre have been obtained on this farm. In the third year no plants survived the insect attack, but on another part of the farm where the insects did not appear a yield of 247 lb. per acre was obtained in spite of the drought.

The dolichos bean yields in the last two years are pitifully poor owing to damage by insects, and in the first season only a moderately poor yield was obtained.

Cowpeas gave the highest yield of hay in the first two seasons. The dolichos beans gave nearly as much hay as cowpeas in the second year but were no better than the velvet beans in the first year. The hay yields from the velvet beans were not high, but this crop was at a disadvantage because the vines could not climb, as they must if maximum yields are to be obtained. It is interesting that the dolichos beans gave very much more aftermath growth than these other two crops and by this means provided more dry-season grazing.

It is very clear from these results that for satisfactory returns from these leguminous crops a much better distributed rainfall is required than we get at Mpwapwa, and it must be assumed that under such conditions the growing of these legumes is a gamble. In areas where the rains are more certain these crops will give much better returns. Under our conditions these legumes reach the limit of their growing capacity; in good years good crops are obtained, in average years only moderate yields, and in bad years the plants may die out or the yields will be so reduced that they are a complete failure.

Summary.—On the basis of three seasons' work it is perhaps premature to draw any conclusions, but the following facts are put forward tentatively:—

(1) *Maharage* beans, peas, pigeon peas and buckwheat are not economic crops under the dry conditions of the Central Province.

(2) The variety of soya bean examined is not suitable for haymaking, but in a normal year can yield 200 lb. of seed per acre. Another more drought-resistant variety is needed.

(3) Of the legumes tested, cowpeas appear to give the biggest yields of hay, and can also give from 500 to 600 lb. of seed per acre in an average year.

(4) Dolichos beans can give almost as heavy a yield of hay as cowpeas in a favourable year, but do not give such a big return of seed.

(5) Velvet beans have done quite well at Mpwapwa; they give moderate yields of hay when grown without a supporting crop for the vines and give a fairly good yield of beans.

Notes on Animal Diseases

Compiled by the Department of Veterinary Services, Kenya Colony

III—PIROPLASMOSIS AND ANAPLASMOSIS OF ANIMALS OTHER THAN CATTLE AND TRYPANOSOMIASIS

Piroplasmosis of Equines (Biliary Fever)

Two species of piroplasms, both of which occur in Kenya, are known to occur in equines. They are *Babesia caballi* and *Nuttalia equi*.

Microscopically, *Babesia caballi* closely resembles *Babesia bigeminum* of cattle in appearance, whereas *Nuttalia equi* is a smaller parasite, more akin to the species of the genus *Theileria*. The latter parasite is much more frequently encountered in Kenya.

Both parasites are tick-transmitted. Transmission of *Nuttalia equi* to susceptible horses by adult *Rhipicephalus evertsi*, that had fed during the larval and nymphal stages on carrier animals, was demonstrated by Theiler in 1905, and it is probable that other ticks may also be capable of transmitting infection. Experimental transmission of *Babesia caballi* by African species of ticks has not yet been effected.

Susceptible donkeys and mules may be infected with *Nuttalia equi* by the inoculation of blood from infected horses; but clinical infections in these animals are rarely observed.

Symptoms.—After experimental inoculation the incubation period in *Nuttalia equi* infection is from seven to nine days. After natural infection the incubation period may be as long as three weeks. In general the symptoms and post-mortem lesions produced by the two parasites are similar. However, with *Babesia caballi* a continuous temperature curve occurs, whereas with *Nuttalia equi* the fever is of the intermittent type.

The first visible sign of sickness is usually a pale yellow coloration of the mucous membranes of the eyes and mouth. Later, in severe cases, small hæmorrhagic points occur in the third eyelid. The animal appears dull and shows lack of interest in its food, while its thirst is increased. During the early stages there is marked constipation, but later colicky pains and diarrhoea may be observed. The urine is usually increased in amount and yellow or reddish-brown in colour. Redwater occurs in rare cases; probably more frequently in severe *Babesia caballi* infection than in *Nuttalia equi* infection. Loss of condition is usually noticeable and in certain cases œdematous swellings of the limbs and sheath are present. Death may occur within four or five days of the onset of symptoms, or may be delayed for several weeks.

Post-mortem Lesions. — On post-mortem examination the most obvious abnormality noticed is a general jaundice of the tissues. The blood is thin, pale and watery, the spleen swollen, and other lesions analogous to those observed in redwater in cattle are usually found.

Immunity.—Recovery from an attack of biliary fever leads to the development of a state of premunity in every way similar to that following recovery from redwater in cattle. The disease caused by *Nuttalia equi* is generally regarded as more severe than that caused by *Babesia caballi*.

Treatment.—Careful nursing and the control of constipation by the use of laxatives and enemata should form the foundations of treatment. Until quite recently direct specific therapy was not on

a very satisfactory footing. Trypanblue may have been of some value in the treatment of *Babesia caballi* infection, but had little or no action on the commoner parasite. Quinine hydrobromide, 1 grm. in 20 c.c. sterile water given intramuscularly once a day for three days, was commonly employed in *Nuttalia* infections. However, within the last few years the use of Acaprin, introduced by Messrs. Bayer, has proved so successful that this drug has now superseded the older methods of treatment.

Piroplasmosis of Pigs

Infection of pigs by *Babesia trautmanni*, a parasite first described from pigs in the Kondoa-Irangi district of Tanganyika, has been observed but once in Kenya. The main symptoms are jaundice and redwater. The pathogenicity of the parasite appears to be low.

Piroplasmosis of Dogs (Tick Fever)

Tick fever is most frequently seen in puppies, newly imported dogs and highly bred dogs. Dogs bred in East Africa usually contract infection early in life and recovery leads to premunization. More frequently than in redwater, however, the blood of a recovered animal will fail to transmit infection to susceptible puppies. The causal parasite, *Babesia canis*, is similar in appearance to *Babesia bigeminum* of cattle; but the infection of one blood cell with more than one pair of parasites, frequently seen in tick-fever smears, is most unusual in redwater. In Kenya the usual transmitting ticks are *Hæmaphysalis leachi* and *Rhipicephalus sanguineus*. In the case of the former species, only the adults are capable of causing infection. Infection is passed through the egg, but neither larvæ nor nymphæ transmit the parasite while feeding. In *Rhipicephalus sanguineus* infection is also hereditary. In this case, however, while the larvæ of an infected female are non-infective, both nymphæ and adults will transmit the disease if fed on a susceptible dog.

Symptoms. — After an incubation period of from four to six days in dogs inoculated with blood or of ten to twenty-one days following the bite of an infective tick, the first indication of illness is a rise in temperature. Within a day or so, dullness, loss of appetite, and an increased desire to sleep are usually noticed. Anæmia is manifested by pallor of the eye membranes and the gums. Constipation is present, the tongue is furred, breathing becomes increased in frequency and the pulse weak and fast. Later the appetite is completely lost and the dog becomes progressively weaker and weaker. Jaundice is often observed; but whilst the urine may be brownish-green in colour owing to the presence of bile pigments, true hæmoglobinuria rarely, if ever, occurs. In acute cases death may occur three to ten days after the beginning of the temperature reaction.

Chronic cases in which the temperature reaction is slight or intermittent are not uncommon in puppies. In dogs so affected there is a progressively increasing anæmia. The animal is listless and its appetite capricious. Condition is rapidly lost. A percentage of these cases develop ascites, that is to say, fluid accumulates in the abdominal cavity, and, even if removed, usually the fluid collects again rapidly. Such cases do not respond to treatment and almost invariably end fatally.

Treatment.—Two drugs are available for the specific treatment of tick fever—trypanblue and Acaprin. Whichever is chosen, the administration should not be delayed too long. The dog should be weighed and the proper dose calculated carefully. Specific treatment should be

accompanied by suitable symptomatic treatment. The patient should be given a warm bed and kept quiet for at least forty-eight hours after the injection. During this period the occasional administration of a little brandy and milk is often helpful, particularly in cases where the pulse is very fast and weak. During convalescence, which should be rigorously enforced, tonics such as Parrish's food or Stovarsol are of value. Exposure to cold and wet should be avoided.

Relapses may occur seven to ten days after treatment. When the patient is properly nursed, specific treatment is usually unnecessary; but if the dog develops a high temperature and goes off his food specific treatment must be repeated.

Piroplasmosis and Anaplasmosis of Sheep

Small piroplasms are occasionally seen in blood smears from sheep in Kenya. They do not appear to be of importance.

Anaplasmosis is also seen occasionally in sheep. Apart from a rise in temperature the reaction is usually symptomless.

Trypanosomiasis

All species of domesticated mammals are susceptible to one or more forms of trypanosomiasis. This disease, usually called "fly," is caused by one of a number of species of trypanosome, unicellular animals whch infect the blood and tissues of the host. These parasites differ from piroplasms and anaplasms in that they occur free in the blood plasma and do not invade the cells.

All the pathogenic species of trypanosomes in East Africa are transmitted by the bites of flies. The parasites responsible for dourine, a disease of equines recorded from North and South Africa, as well as from other parts of the world, are transmitted from the mare to the stallion and vice versa at service.

The species of pathogenic trypanosomes that have been recorded from Kenya are *Trypanosma brucei, T. vivax, T. congolense,* and *T. evansi.* The first three of these are transmitted mainly by tsetse-fly, although it has been shown that on occasion other biting flies (for example, the widely distributed species of *Stomoxys*) may be responsible for mechanical transmission once infected cattle are introduced into a clean area. The disease caused by these species of trypanosomes, usually called "nagana," is, however, rarely of economic importance except in fly belts and adjacent areas. The species of tsetse of major importance so far as animal trypanosomiasis is concerned in East Africa is *Glossina pallidipes,* but other species of the genus *Glossina* are potential transmitters of these parasites. *Trypanosoma evansi,* the cause of surra, is transmitted by tabanid flies and possibly by *Ornithodoros* ticks.

Fly belts in East Africa are rarely clearly demarcated areas. Under certain climatic conditions tsetse-flies, in particular *Glossina pallidipes,* show a tendency to migrate from their habitual breeding grounds and to occupy temporarily new territory. This process is known as dispersal, and accounts for outbreaks of fly in areas adjacent to, but not usually considered as parts of, recognized fly belts. Sporadic cases of fly may be caused by tsetse that have been carried from their usual haunts by motor cars, railway carriages, or other vehicles, or that have followed herds of game on migration.

Surra in East Africa is mainly a disease of camels, and in Kenya is restricted to parts of the Northern Frontier District and to the coastal belt.

Whilst the train of symptoms produced by the different species of trypanosomes in East Africa is generally similar, the species vary in their pathogenicity for the

different domesticated animals. It is important to note also that various strains of each species are recognized that differ amongst themselves in pathogenicity.

Trypanosoma congolense is probably the commonest species causing nagana in cattle. In addition, strains of this species are usually highly pathogenic for dogs and pigs. Sheep, goats, and equines are somewhat less susceptible. As a parasite of cattle, *Trypanosoma vivax* is next in importance in Kenya. Sheep and goats may also be found infected, but horses are relatively insusceptible and dogs are resistant. *Trypanosoma brucei*, on the other hand, is highly pathogenic for horses, camels, dogs and pigs. Cattle, sheep and goats, although they react to the extent that after inoculation parasites may appear and multiply in their blood, show no marked symptoms of infection.

Trypanosoma evansi has a similar pathogenic range to *T. brucei*. Surra is essentially a disease of horses, camels and dogs, whereas in cattle a mild, chronic form occurs, the majority of animals showing little or no outward evidence of infection.

In addition to the pathogenic species, a large trypanosome, *T. theileri*, is commonly encountered in cattle. This species, which is in all probability transmitted by tabanid flies, is rarely of economic importance. Premunized animals may, however, relapse to infection when reacting to some other disease, such as rinderpest, thus increasing the severity of the reaction.

Symptoms—Cattle.—In cattle infected with *Trypanosoma congolense* the first evidence of infection is a rise in temperature five to ten days after exposure. In the case of work oxen visible evidence of infection may be present five to seven days later; but in other cattle the disease often develops slowly and several weeks may elapse before untoward symptoms are noticed. Such symptoms are dullness, lack of appetite, and lack of energy. The animal shows discomfort when the eyes are exposed to strong light, and there is some lachrymal discharge. Further symptoms gradually become evident. The animal falls off in condition, the eyes appear sunken, the coat becomes staring, and in milch cows there is a reduction in yield. The lymph glands may be sufficiently swollen to be visible, as in east coast fever, and diarrhoea may be observed. In the final stages the eye often becomes opaque, the animal is extremely emaciated and very weak. A percentage of cattle show œdematous swellings of the throat, dewlap and belly.

The progress of the disease is always hastened by exposure to cold or rain, or by working.

Infection with *T. vivax* leads to a similar, but milder, infection in cattle. Housed cattle, if well fed, may show few definite symptoms, but symptoms may be noted in work oxen and in infected cattle moved to cold, wet districts.

Pure natural infections of cattle with *T. brucei* and *T. evansi* are rarely observed in East Africa. It may be pointed out, however, that it is not uncommon for an animal to be infected with more than one species of trypanosome.

Equines.—Following infection with *T. evansi* and *T. brucei*, the more pathogenic trypanosomes for horses, mules and donkeys, trypanosomes may be found in the blood in from five to eight days. The temperature curve in these animals is usually irregular, showing peaks at varying periods. A tendency to avoid light and a watery discharge from the eyes, muscular stiffness, dullness and depression, are usually present, whilst œdematous swellings of the legs and abdomen may be noticed for varying periods. In

the later stages loss of condition is progressively more marked, and the animal becomes very weak. Opacity of the eye is usually seen.

Milder symptoms are usually evinced when equines are infected with *T. congolense,* and the infection is not always fatal. As in the case of cattle infected with fly, however, work and exposure to inclement weather will frequently precipitate a more severe form of the disease. *T. vivax* is of little significance in equines.

Sheep and Goats.—The smaller ruminants are on the whole relatively resistant to trypanosomiasis. Natural cases of *T. congolense* infection in sheep have been observed in the coastal region of Kenya and in parts of the Masai Reserve, and infections with *T. brucei* and *T. vivax* have been recorded in other countries. The symptoms shown are emaciation, œdematous swellings, running at the eyes, and an irregular temperature reaction.

Camels.—Surra in camels may run a "rapid" course, death occurring within a few months, or the infection may be more chronic, lasting several years. The animal loses its appetite and becomes easily tired. The eye is dull and paroxysms of fever occur at intervals. Oedema of the abdomen, sheath and pads is sometimes seen. In the more slowly developing cases, emaciation is very marked, and paralysis may be observed before death. Such cases often terminate with a secondary pneumonia.

Dogs.—Dogs are highly susceptible to infection with *T. brucei, T. evansi* and *T. congolense.* The course of the disease is, however, as in other animals, chronic. There is a primary temperature reaction, followed by an irregular up and down curve. Lack of appetite and progressive wasting are noticed. Eye symptoms develop early, opacity of the anterior membrane of the eye being frequently seen. Oedematous swellings of the legs are particularly common in *T. brucei* infections. Jaundice may be present. In the later stages there is great weakness and apathy. Breathing appears difficult and the pulse becomes almost imperceptible.

Dogs are usually relatively resistant to *T. vivax* infection.

Post-mortem Lesions.—A definite diagnosis of trypanosomiasis can rarely be given from the appearance of the organs alone. The carcass is emaciated, anæmic and the subcutaneous tissues and the muscles are watery. The spleen may be enlarged, the lymph glands swollen and soft.

Diagnosis. — Although trypanosomes may be numerous in the blood during the early stages, they become scanty as the disease progresses. In animals showing an irregular temperature curve, there is an increase in numbers during the period in which the temperature is elevated, and in some cases a further increase occurs in the blood shortly before death. When possible, therefore, smears for diagnosis should be made while the temperature is high. Wet smears are often a help in making a diagnosis. In a drop of blood placed on a slide and covered with a cover-slip the motile parasites can often be detected under the lower power of the microscope much more readily than they can be found by searching a stained smear with an oil-immersion lens. Gland smears may reveal the presence of parasites when blood smears are negative, and are particularly useful in *T. vivax* infection.

Immunity.—When natural recovery from an attack of trypanosomiasis does occur, premunity similar to that following redwater and anaplasmosis infection, but more unstable, frequently develops. The animal becomes a carrier, and relapses may occur is the animal is exposed to

unsuitable conditions or if it contracts some other disease. Drug treatment of infected animals may result in the destruction of all the parasites, when the animals become completely susceptible to re-infection.

The game animals of Africa complicate the control of nagana. In fly belts, antelopes and other game harbour infection without showing symptoms, and hence act as reservoirs of infection. Similarly, camels and, to a lesser extent, cattle act as reservoirs of infection of the parasite of surra.

Treatment.—The treatment of trypanosomiasis is a wide and difficult subject, and only a brief summary can be given here. Early cases of *T. brucei* and *T. evansi* infection usually respond to treatment with Naganol (Bayer 205) and its English and French representatives, Antrypol and Fourneau 309. Once the disease is advanced, however, there is little hope of effecting a cure. In *T. vivax* infection a number of drugs which will usually produce a cure (tartar emetic, Antimosan, and Congosan (Surfen C), for example) are available. In *T. congolense* infection treatment is often useless. Many cases respond to repeated doses of tartar emetic or Antimosan or to single doses of Congosan, but in some animals these drugs produce no effect. The Naganol compounds are of no value in cases caused by *T. congolense*.

Control of Trypanosomiasis. — Although in certain circumstances the destruction of game animals, that act as reservoirs of the parasites and provide the main food supply of the tsetse flies, has done much to eliminate trypanosomiasis, the main trend of modern experimental work is towards the discovery of cheap and efficient methods of eradicating the fly. A vast amount of work has been done on this subject, and it is impossible to deal with it here. Each fly area appears to present a distinct and individual problem, and methods of attack likely to be successful can only be devised after a detailed survey by an entomologist who has specialized in this subject. Such methods of attack can even then be regarded as only experimental and as more likely to lead to a reduction in the numbers of fly than to complete eradication.

A warning may not be out of place as to the dangers of attempting control without expert advice. As an example of the intricacy of the subject, it may be mentioned that, in certain areas, regular grass burning, carried out under a definite plan, has led to a marked reduction in the number of fly, whereas, in other areas, the prohibition of grass burning has produced the same effect. Probably the only generally successful method of combating fly is the introduction of dense, compact agricultural development of the area. Unfortunately, in many dry, infertile districts such development is not possible.

Construction of Farm Roads and Bridges

By H. A. CAMPBELL, *A.M.Inst.C.E., M.Mun. & Cy.E., Executive Engineer, Public Works Department, Kenya Colony*

Roads on farms can be divided roughly into two categories, viz:—

(*a*) Roads giving access to and egress from farms.

(*b*) Administration roads giving access from one part of a farm to another.

The principles underlying the location and construction of both categories are identical, except that the standard of category (*b*) can usually be much lower than that of category (*a*). Except on large estates, such as sisal and tea undertakings, administration roads within a farm are not of major importance. Large estates usually have engineering advice available, and the object of this article is to lay down a few guiding principles for those who have not ready access to technical advice.

LOCATION

The most trafficked road on the majority of farms is that which gives access from a public road to the farmer's residence and farm buildings. The homestead is usually on rising ground, whilst the public road is often on an adjacent ridge or in a nearby valley. Such being the case, it is necessary for the farm road to negotiate rising and/or falling ground to reach its objective.

Engineering advice on location is usually not possible, but errors in location often result in heavier charges for upkeep which could be avoided by thoughtful planning in the initial stages. The writer considers that separate motor and wagon roads should be provided because, although the farmer may be disinclined to embark upon the expense of providing two roads, it has been proved ultimately to be a true economy. Wagons using a motor road cause damage which results in the necessity for constant repair in order to keep the road open to motor vehicles, whilst corresponding damage on a road designed for wagon traffic only would go unmarked and would cause practically no inconvenience or expense.

In road construction of any description "ruling" or maximum grades should be laid down, and in areas where tropical storms are experienced more attention should be paid to keeping the ruling grade within reasonable limits than where heavy precipitation in violent storms does not occur. The writer has heard it argued that the modern motor vehicle will negotiate 10 per cent (1 in 10) and 12 per cent (1 in 8.5) grades with ease when laden, but considers that this should not be the basis for establishing ruling grades in this Colony. No matter whether public or private roads are under consideration, it is found that where grades exceed $6\frac{1}{2}$ per cent (1 in 16) scour during heavy rain reaches serious proportions. Although traffic on farm roads will naturally be a great deal lighter than on a public road, the number of culverts per mile will be less upon the former than on the latter for reasons of economy in construction, whilst the crossfalls will probably not be so carefully maintained. For these reasons storm water will tend to drain down depressions, such as wheel-ruts, in the riding surface, the damage being greatly increased once a grade of $6\frac{1}{2}$ per cent is exceeded. It will be obvious, even to the most inexperienced, that the steeper the grade the farther storm water will flow down the roadway before discharging itself at the side, and the more damage it will cause. For these reasons it will be

seen that economy in permitting excessive grades to reduce costs of construction will result in expense, annoyance and inconvenience when the road is in use.

The location of roads is often determined by suitable stream crossings, although it is useless to select sites for the latter to which the approaches are so difficult as to render the cost of their construction disproportionate. The cost of the approaches and the bridges or drifts should be studied in conjunction with one another, in order that the most economical site may be decided upon. Where the approaches to streams involve fairly long descents from ridges, the writer has generally found that it is easier to work down hill, carrying out the location reconnaissance. The country to be traversed can then be reconnoitred from points of vantage and natural obstacles will be obvious before being encountered.

As far as possible, heavy forest should be avoided on account of the difficulties of location, expense of construction, usually unsuitable soil, and the desirability of preserving trees. Naturally the road should not cross swampy ground, but it may be remarked that it is usual to find hard-surfacing of fair quality within about 3 ft. 6 in. of the surface of genuine black cotton soil. It is therefore often an advantage to run along the sides of a *vlei* where surfacing of the quality referred to is available. As far as possible roads should adhere to ridges or high ground in preference to following valleys, the reason being that where a valley line is followed considerable expense is usually necessary in the provision of crossings of the tributaries of the main stream. It should be noted that roads should not be located along the top of any ridge but rather just below the top, as drainage of a road constructed along the top of a ridge is difficult on account of small depressions, etc. When the road is just below the summit, disposal of storm water is a simple matter. Cross drains or culverts may be necessary, but with proper location will be reduced to a minimum.

The section dealing with location may seem unduly lengthy, but if it is appreciated that maintenance of a good location is probably less than half that of a bad one the need for stressing the importance of preliminary reconnaissance will be evident.

Construction

It has been said with truth that the first law of road construction is drainage, and that the second is drainage and that the third is drainage. Even in the higher types of road construction, adequate drainage is necessary, as most failures are due to inadequate provision for the disposal of surface water. When it is realized that the lighter forms of surfacing, natural or bituminous, are adopted largely for the purpose of waterproofing and shedding surface water quickly, the importance of drainage becomes more apparent. Therefore, where funds are strictly limited, it is advisable to devote the major portion of the money available to this fundamental of construction. It will be readily seen therefore that careful location will result in an ultimate saving in this all-important expenditure.

The width of an ordinary farm motor road need not exceed 12 ft., provided that regular passing places are constructed, and crossfalls should not be more than 1 in 20 or less than 1 in 24. In side-long ground, the crossfall of which does not exceed 3 per cent (1 in 33), the orthodox cambered surface is unnecessary and the road may be constructed to fall in conformity with the crossfall of the country over which it is constructed. Where the crossfall is steeper, the road

should be so constructed that it falls against the natural fall of the ground and has its lower edge upon the inside. In such cases catchwater drains about 6 ft. from the inside edge of the road should be dug, the spoil being deposited between the road and the drain, and the water led across the road at, say, intervals of 400 ft. by primitive stone culverts, formed of empty cement drums with a cover of not less than 18 in., or paved "Irish bridges." The latter are shallow depressions cut across the road, with slopes of not more than 1 in 12—if the farmer values the friendship of his visitors who do not know the road. *On no account should main drains be cut along the inside edges of roads on steep grades,* as they gradually scour deeply, and become extremely dangerous; when grades are encountered culverts should be generously disposed if scouring and cross runnels are to be prevented.

Curves are not a matter of vital importance on a farm road, but on any farm motor road a curve of not less than 200 ft. radius should be aimed at. On wagon roads the radius of curvature should be such that at least one span of sixteen oxen and a large South African wagon can be accommodated on any portion of a curve in such a manner that full advantage can be taken of the whole span, i.e. that all can get a straight pull at one time.

Provided that a comfortable riding surface has been obtained and drainage is not interfered with, it is advisable to induce the growth of suitable types of grass upon farm roads, as disintegration by rain and traffic is thereby prevented. It will usually be necessary to remove most of the natural grass, but do not dig deeply, as this often converts the road into a natural watercourse. Storm water should be led from the sides of the road at regular intervals, according to grade, by mitre drains leading to open ground or catch-water drains. All weak places should be surfaced after attention has been paid to drainage, and it should be borne in mind that it is usually cheaper to remove 3 ft. of overburden than to haul 300 ft. The borrow pits so dug will, in addition, be available for digging subsequent surfacing material for maintenance.

The ideal is, of course, to surface the road throughout, and a thickness of 3 in. in the loose to a width of 9 ft. should be ample for motor traffic. Where this ideal cannot be obtained, hard-surfacing of the worst types of soil crossed should be carried out. It has been found that in average murrum a good Kavirondo labourer can dig, wheel and spread 100 cubic feet per day, the maximum haul or carry being 100 ft. It is not expected that this standard will be attained by a small gang, but it indicates the task which can be performed by experienced labour under close supervision on task work. Squatter labour would probably not be able to perform half such a task.

Bridges and Culverts

For the purposes of this article it is difficult to define the difference between these two types of structures, but it is assumed that a culvert is merely a single opening not exceeding 3 ft. wide for passing water under a road. Where the expense can be borne, galvanized corrugated iron culverts should be put in, but it is realized that most farmers cannot embark on such expedients. In such cases old cement or bitumen drums can be acquired cheaply, and with the ends removed make a satisfactory type of culvert when placed end to end. The ends should be fitted as well as possible and the sides and top surrounded with hard-surfacing. A cover at least equal to the diameter of

the culvert should be given, but stones bigger than 3 in. should not be placed alongside the culvert, as these tend to cause punctures. Avoid "humped" culverts—they make enemies. The bottom of the culvert should be set at a depth equal to at least twice its diameter, but should it be impossible to sink it so deeply the road surface should be graded up on each approach to about 1 in 15. "Sunked" culverts can be avoided by laying the cover in layers of not more than 9 in. and tamping each layer thoroughly. Culverts should always be rather longer than the width of the carriage-way, and marking with stakes is an advantage.

Where it is possible to obtain stone which laminates, or flakes, in large pieces, good dry-stone culverts can be built by semi-skilled labour. Even French drains, i.e. trenches filled with stone, are better than a cross runnel, and the farmer can make such culverts satisfactorily where large stones are available, although they may be overtopped in heavy storms. If the stone is carried up to the surface the resultant damage due to overtopping should not be serious.

The question of bridges opens a wide subject, but it is unusual that a farm road requires a large span bridge. Also it is usually quite unnecessary to construct high-level bridges, as most streams rise and fall rapidly, and are soon negotiable after storms are over. The farmer should therefore determine the normal water level during the rainy season and construct his stream crossing to permit of its being passable under such conditions. Once again old cement drums surrounded by broken stone may be utilized as culverts, and up-stream and down-stream head-walls, carried to rock or hard foundations, should be built. Should no suitable foundations be encountered within two feet, apron or drop walls to this depth should be constructed. The surface of the drift should be concreted, or a very good and cheap surface can be constructed of pre-coated bituminous chippings, about 1 in. thick, well compacted.

Where a high-level bridge is necessary, and good cedar, *msharage* or *mwere* available, substantial wooden bridges can be built. These should be on wooden bents or trestles, with longitudinal timber bearers. The trestles should consist of roughly squared trees with uprights, sills, and headers about 10 in. x 10 in. These should be set on concrete if possible, and rivted at the back with old corrugated iron or stone. The trestles should be substantially constructed, being mortised and fixed securely with dog-spikes.

The subject of bridges is so wide that it is not possible to generalize in regard thereto, as each problem must be treated individually.

Conclusion

The subject of this article is one which is of interest to a large proportion of the farming community, and the writer has endeavoured to set the broad principles which govern the construction of farm roads. Each road presents its individual problem, and it is hoped that the views put forward will be of assistance to those who are confronted with construction or maintenance of farm roads. An endeavour has been made to avoid technical terms and to frame the advice offered in language readily understandable by all.

A Trap for Bush Pig

By O. R. ARNELL, *Kitale, Kenya Colony*

This year my maize guards have killed seven pigs and five porcupines round a twenty-five-acre field of maize with traps of the type described below, whereas they failed to catch any with a leopard gin.

These traps have the following advantages over trap-guns:—

(1) The squealing of any pig caught frightens away all pigs from the vicinity for several days.

(2) There is no danger of injuring human beings, and so the traps can be left set indefinitely, thus decreasing the chances of the pigs' suspicions being raised.

(3) The traps cost nothing and are easily made and set.

The materials required are:—

One stout sapling, 10 or 12 ft. long.

One piece of cord 5 or 6 ft. long.

One piece of fencing wire (8 or 10 gauge), 7 or 8 ft. long.

Two stout pegs cut from forked sticks.

A number of sticks about $\frac{3}{4}$ in. in diameter and about 18 in. long.

The fencing wire is formed into a running noose and attached to the thinner end of the sapling. The cord is also attached to the thinner end of the sapling and its other end tied to a short piece of stick, called the "trigger" in the illustration. The pegs are driven into the ground at the edge of a run frequented by pigs and the sapling driven into the ground about 6 ft. from the run and sloping towards the pegs.

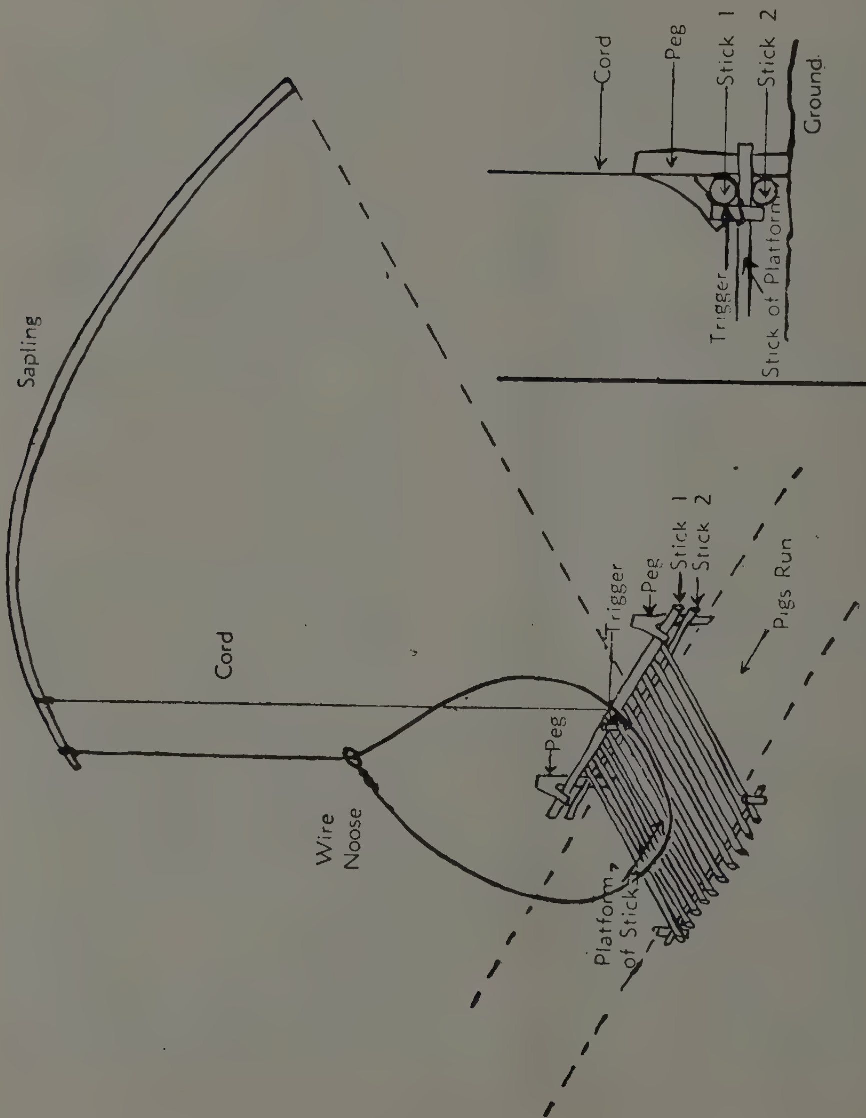
The sapling is bent down and held by the cord, the "trigger" resting against two sticks which are held down by the pegs. If the lower stick (stick 2) is pressed down the trigger is released and the sapling springs up. A number of short sticks are laid across the run, just above the ground, the ends resting on "stick 2" and the wire noose is arranged above the run. (It may be an advantage to have two wire nooses.)

The opposite ends of the short sticks rest on a stick laid on the ground on the opposite side of the run, and are kept in place by two short pegs.

A pig coming along the run puts its head through the noose and, at the same time, treads on the sticks across the run, thus releasing the sapling, which springs up and draws the noose tight. The maize guards, hearing the squeals, comes and kills the pig with his spear.

Traps should be set in every run which is found.

(*See illustration on next page*)



TRAP FOR PIGS

Nodule Bacteria and Leguminous Cover Plants*

By F. Beeley

It is a pleasant change from the usual lectures on harmful disease organisms to have to tell the story of the biology of the very interesting and agriculturally very important group of organisms known as the "Nodule organisms". These organisms were originally classified as variants of the species *Bacillus radicicola* but to-day the class is so great as to justify the generic term *Rhizobium* of which many species, specific to various plants, are recognized.

Ancient history yields ample evidence of the importance of nodule-bearing leguminous plants in mediaeval agriculture and earlier not only in Asia but also in the old Inca American world where both the food value and the soil fertilizing value of these crops were early appreciated. Later in Egyptian and Roman times we find abundant evidence of the part played by leguminous plants in agriculture and in religious and funeral rites.

In later European agriculture about the nineteenth century various workers demonstrated the fertilizing value of cultivating a legume crop with cereals in order to obtain better yields of the latter. This was soon enlarged upon and the modern idea of rotation of crops became established. The problem as to how the legume crops increased the fertility of the soil exercised the minds of many scientists during the later half of the nineteenth century. Various theories were put forward but it was not until 1886 that Hellriegel announced his great discovery of the beneficial activity of micro-organisms in the nodules, in that these micro-organisms absorb and fix nitrogen from the air and make it available to the plant.

Tropical forest countries are particularly rich in nodule-bearing leguminous plants. In addition there are other genera of plants which bear similar nitrogen-fixing nodules, e.g. *Cycadaceae*, *Podocarpus* and *Casuarina* sp., distributed in many tropic and temperate climates.

The *Leguminosae*

The terms "legumen" and "leguminous" are derived from the Latin verb *legere*, to gather, and are construed to mean plants gathered with the hands and not cut in harvesting. Botanists, however, now use the term "legume" in a more restricted sense as meaning the characteristic fruit or pod of the *Leguminosae*. Hence the present day terms "leguminous plants" or "leguminous crops" when speaking of the plants themselves.

This large family of plants is easily recognized by the butterfly-like flowers, in which the two lower petals are united to form a keel and so enclose the stamen and pistil. There is a single free pistil which develops into the pod or legume, which is dehiscent by one or two sutures into two valves.

To-day the family *Leguminosae* is the second largest in the plant world and representatives are found in all climates and soils from the arctic to the hottest tropical regions. They play a great part in the building up and reclaiming of soils. Even on waste tin tailings leguminous plants are among the earliest to establish themselves.

Campbell (1927) studied the revegetation of gravel wastes and of worn-out and abandoned farm land. In the first period of return to nature the *Leguminosae* may

*Reprinted from the *Journal of the Rubber Research Institute of Malaya*, Vol 8, No. 2, Jan., 1938.

constitute 75–100 per cent of the plant population. But as such soils again increase in fertility in consequence of the growth of the *Leguminosae* themselves, the flora changes. The *Leguminosae* recede and other plants come in. He even went so far as to suggest that the relative abundance of *Leguminosae* in any wild association of plants constitutes an ecological index to the fertility of the soil.

It is difficult to estimate the amount of nitrogen which these plants assimilate and to estimate what chemical value they are to the soil, while of the cultivated leguminous crops one has to consider both the market value as well as their intrinsic value in the agricultural system. Certain of the *Leguminosae* yield valuable foods, woods, oils, dyes and medicinal or poisonous products. It is even claimed that anophelene mosquitoes feeding partly upon juices of toxic leguminous plants are unable to spread malaria though carrying the parasites.

Agriculturally the value of leguminous plants in threefold: (*a*) as a food or fodder crop, (*b*) as fertilizers of the soil and (*c*) as cover plants.

Investigating how the legumes improve soil fertility, Hellriegel found that though legumes in themselves cannot assimilate nitrogen from the air, yet through the symbiotic life of the micro-organisms in the nodules attached to their roots they are able to do so, to the joint benefit of plant, organisms and soil.

It may now be asked what is meant by the term "symbiotic life", i.e. symbiosis.

SYMBIOSIS

The term "symbiosis" is derived from the Greek, meaning "living together", though modern usage, in view of the existence of the commonly-used terms parasite, saprophyte, epiphyte, etc., attributes to the word the more limited meaning "the association of *mutually beneficial* organisms, of which the nodule organisms of the *Leguminosae* and the *mycorrhiza* of a number of other plant genera (*Ericaceae*, Conifers, etc.) are clasical examples.

Several species of tropical plants are known to possess colonies of nitrogen-fixing bacteria in their leaves which are visible as flat nodules on the leaf lamina or as special processes on the edges of the leaf. The leaf of the well-known Tulip tree (*Spathodea* sp.) is very common in Malaya, growing vigorously in most garden soils and is found to bear nitrogen-fixing nodules in abundance on its leaves. Among other genera of plants which bear similar nodules on the leaf are *Pavetta, Psychotria, Ardisia* sp., etc. It would be interesting to know to what extent these species have played a part in, or been used specifically for, the improvement of soils during the past few years on rubber estates where natural covers have been established. Of the *Leguminosae* practically all species bear the nitrogen-fixing nodules on their root systems providing the correct symbiotic organism is present in the soil in which they are growing. There are, however, a few exceptions. While the sub-families *Papilionoideae* and *Mimosoideae* (except an Acacia sp.) generally bear nodules; the *Caesalpinioideae* show several exceptions which to date are *Cercis* sp., *Gymnocladus* sp., *Gleditsia* sp. and *Cassia* sp. Some authorities suggest that these may have other means of maintaining symbiosis with nitrogen-fixing bacteria.

It is important to remember that there are many different strains of nodule organisms, each specific to a certain species or group of plants, and of no use to other legumes. Unless the particular strain of nodule bacteria specific to a given legume is present, that legume is

unable to form nodules and to assimilate atmospheric nitrogen, even though other strains of nodule bacteria specific to other plants are present.

Types of Nodules

Firstly note the difference between true symbiotic nodules and false nodules. There are two recognized types of false nodules produced: (*a*) by the nematode *Heterodera radicicola,* a tiny eel-worm; and also (*b*) by the crown gall bacterium *Phytomonas tumefaciens*. Either of these false nodules may be found on leguminous plants bearing also true nodules.

The nematode nodule usually takes the form of swelling or enlargement of the root cylinder. The crown galls are usually found at the crown of the root and are of an irregular shape very different from the bright coloured, rounded, nitrogen nodule.

True Rhizobium nodules, when young, are usually of a smooth rounded, elongated or club-shaped form. As the first nodules grow in size other nodules may bud off from the larger ones thus forming a cluster or mass of nodules.

Generally speaking cultivated annual *Leguminosae* have large, spherical or irregular nodules. Perennial *Leguminosae* tend to develop smaller nodules in elongated clusters. Specimens of nodules of the more common legume cover plants and of eel-worm nodules are shown. The number of nodules to be found on any single plant ranges from a few to several thousand widely distributed over the tap and lateral roots. The greater number of nodules does not necessarily mean greater benefit to the plant, in fact some authorities are of opinion that a few large nodules on the main roots and more on the base of the stem are more efficient from the point of view of nitrogen fixation and benefits to the plant.

Isolation of the Nodule Organisms in Pure Culture

If due care is taken and absolutely clean technique is used it is comparatively easy to obtain pure cultures on ordinary bacteriological media.

The procedure is as follows:—

1. Select nodules only from vigorous plants, and select true nodules of a plump, healthy rosy colour, avoid nematode nodules, root swellings and galls.

2. Wash the nodules free of earthy matter in a stream of water.

3. Clean and sterilize the external coat of the nodules by immersion for two to three minutes in 0.2 per cent solution of mercury perchloride in water acidified with a few drops of hydrochloric acid.

4. Wash in successive changes of sterile water for at least half-an-hour.

5. With sterile forceps place the nodules in a sterile glass petri dish, and then cut them up with a sterile scalpel and place the pieces into a tube of nutrient agar, squashing them on the inside of the tube then smearing the nodules over the surface of the agar slope.

Growth on the agar slope is usually satisfactory after about three or four days' incubation at room temperature.

Sometimes several different organisms may be obtained from the same nodule, in which case the various types must be inoculated into nitrogen-free liquid tube cultures containing a living plant of the same species as that from which the nodule was taken. The organism reproducing nodules in these plant cultures is the one required.

Several cultures from cover plants used in rubber agriculture are shown in the exhibits demonstrating the production of nodules on *Centrosema pubescens*.

Requirements of Rhizobia in Culture

It has been stated above that reasonably good cultures of these bacteria can be obtained on ordinary bacteriological culture media. The writer normally uses D.I.F.C.O. Dextrose agar or Potato Dextrose Agar. Agar media made from vegetable extracts have not given such good results as Dextrose Agar.

Some authorities, however, prefer to use special nutrient solutions and solid media containing no nitrogenous substances, in order to limit the specific growth to that of the atmospheric nitrogen-assimilating organisms. The use of such media for the purpose of isolating these bacteria may give very misleading results and often serves merely to hide lack of attention to correct manipulation and technique. The medium in general use to-day is one of these, namely, Mannitol-Phosphate agar, upon which some of the nodule bacteria can thrive but others scarcely grow at all. When a culture is received in this laboratory from other countries it is subcultured on to a number of media in order to find upon which medium it will grow best, and in this way cultures which appear to have made no growth on the medium upon which they have made their long journey and are at first labelled dead or suspiciously so, often prove to exhibit vigorous growth on the Dextrose Agar.

Laboratory culture has shown that these organisms require particularly calcium, potash and phosphates together with an abundance of fresh air. If tubes are sealed or tightly plugged with cork, growth is poor and death of the cultures soon takes place. Light plugging of tubes by cotton wool, or daily aeration of liquid cultures serves to ensure as long a life as possible for these cultures.

In the liquid tube cultures good growth of both plant and organism has been obtained by blowing air each day through the long piece of glass tubing which is inserted in each culture tube.

The liquid for the cultivation of both plants and Rhyzobia consists of the following:—

Potassium Chloride: 1.00 gm.
Calcium Sulphate: 0.25 gm.
Magnesium Sulphate: 0.25 gm.
Calcium Phosphate: 0.25 gm.
Ferrous Sulphate: 0.25 gm.
Distilled Water: 1,000 ccs.

The plants are usually obtained from washed sterilized seed germinated in sterile sand in covered dishes. When ready for transference at seven to fourteen days' old, as much sand as possible is washed from the roots by sterile water and the seedling placed in the cotton wool plug of the tubes which have previously been sterilized in the autoclave. The tubes are then jacketed with black paper to keep off the light from the roots and inoculated with a sterile platinum loopful of the culture under test. The plants are then exposed to light for a few weeks, taking care to aerate the tubes each day. In the case of *Centrosema*, nodules will appear within three to six weeks if the culture is of the right type.

Requirements of Nodule Bacteria

Some authorities say that temperature, sunlight and acidity have considerable effects on the growth and efficiency of the nitrogen-fixing nodule bacteria. It has now been shown fairly conclusively that these organisms can withstand temperatures of 0°C. to 50°C. (32° to 122°F.) showing optimum activity and growth at 20° to 28°C. (68° to 82°F.) Hence their occurrence in both arctic and tropical countries. They are tolerant to moderate sunlight and even ultra-violet light if not exposed for too long, though they thrive better in comparative darkness. Although most of the known species flourish under

neutral or only slightly acid conditions they are known to be tolerant to acid and alkaline soils in which they develop variant types adapted to the particular reaction of the soil in which they are growing. This formation of variant types under different soil conditions is of importance in Malaya, where one finds not only variation in texture and composition of soils but also in the degree of acidity of the soils, most of which are decidedly acid.

The wide range of tolerance of these organisms gives good cause to believe that leguminous cover plants can be grown successfully on most Malayan rubber lands.

Mechanism of Nitrogen Assimilation

Various theories have been put forward by biologists to explain how the atmospheric nitrogen is absorbed and combined with the elements in such a way as to provide nitrogenous compounds suitable for absorption into the plant or for excretion from the roots into the soil.

It is known that the ordinary rod-shaped Rhizobium undergoes various changes in its life cycle within the nodule. Some of these changes involve the formation of bacterioids which are protein bodies unrecognizable as bacteria. It is thought that these bacterioids are, by digestion, absorbed wholly or in part, by the plant, thus supplying protein required for the growth of the plant. That such transference does occur can easily be demonstrated in culture work and in the field.

Most of the Rhizobia, when in vigorous growth, form a mucilaginous matrix of carbohydrate nature, which some authorities assert is capable of absorbing nitrogen from the soil air and transferring it into protein compounds. Another explanation is that the bacteria themselves are capable of absorbing nitrogen, transfering it into protein compounds in their own bodies, which, after death, are digested by the plant-root juices into lower protein compounds and, as such, transported to other parts of the plant. The very high birth rate and death rate of these organisms must render available comparatively large quantities of nitrogenous material which is, surely, absorbed by the plant.

In the cultures exhibited there are abundant free *Rhizobia* in the liquid and it seems reasonable that these organisms derive carbohydrate food from the juices exuded by the roots, while in return these roots will receive the digested bodies of the dead bacteria to the ultimate benefit of the plant. In the cultures inoculated by organisms which have failed to utilize the root juices of the plant growing thereon, no such multiplication and death of these organisms can take place, and the plant receiving no nitrogenous food must succumb. Thus, in such critical cultures a truly beneficial relationship between plant and organisms must obtain to produce the required growth of both.

Laboratory Experiments with Nodule Bacteria

During the last few months eleven species or varieties of *Rhizobia* have been isolated from various cover plants normally used on rubber estates in Malaya, and in addition Mr. Hamilton of the Soils Division of the Rubber Research Institute, has obtained from Rothamsted and from Wisconsin, U.S.A., some sixteen pure cultures of *Rhizobia* isolated from the *Leguminosae* of sub-tropical and temperate climates, which are now being subcultured and tested for their nodule-forming properties on local cover plants, *Centrosema, Desmodium, Vigna, Pueraria, Tephrosia, Crotalaria* sp., etc.

In the tube cultures exhibited, the *Centrosema* plants were inoculated when about ten days old by the application to the roots, under sterile conditions, of a small drop of a vigorous culture of the organisms on agar. Air was blown into the tubes daily and the water level maintained by the addition of more nitrogen-free mineral solution as required. There was no drainage or changing of the liquid in the tubes.

In the case of some of the species of *Rhizobia,* nodulation was visible within two to three weeks. Photographs were taken at intervals of four and eight weeks after inoculation.

The results, briefly, are as follows:—

(1) Nodulation beneficial to both plants and organisms can be obtained with cultures derived from field plants of the same species as the one inoculated. Of the three varieties of organisms obtained from *Centrosema* there are indications of a difference in vigour and nodulation properties of each.

(2) That vigour of growth and depth of green colour of the *Centrosema pubescens* varies directly with the size and degree of nodulation upon the roots. Under the conditions of these experiments support is given to the theory that the development of large nodules, few in number and concentrated high up on the tap root and main lateral roots, is the desirable type of nodulation and is indicative of true symbiosis and positive benefit to the plant.

(3) Other species of *Rhizobia* have no effect or produce non-beneficial nodulation, resulting in ultimate death of the *Centrosema* plants.

(4) One species of organism, while producing fair nodulation, has a detrimental effect upon growth of the *Centrosema.* In this case the organism is living entirely parasitically upon the cover plant.

It is noticeable that in the tubes containing plants free from nodules the aerial parts are starved in order to afford extra root development in an attempt to find a source of nitrogenous food.

(5) There is also some evidence of antagonism between organisms when a mixed culture is inoculated into the roots. If a nodule organism specific to the plant inoculated is used then successful nodulation may be expected, but if a second non-specific species is used the amount of nodulation may be reduced and the benefit to the plant correspondingly reduced.

(6) The *Rhizobia* isolated from *Pueraria, Mimosa,* Soya Bean, produce no nodulation or other beneficial result when inoculated on to the roots of *Centrosema pubescens.*

There are, however, recognized groups of organisms of this type which will cross-inoculate into groups of plants other than that from which they were originally obtained. Experiments are now in progress to test the specific character of all the organisms now in culture and also to find which organism will cross-inoculate leguminous species with a view not only to finding the beneficial types, but also to finding the inhibitors and truly parasitic types of nodule organisms, species for species.

The importance of the latter is only just now being realized and several workers in this sphere of biology have discovered that the much dreaded phenomenon known as Clover Sickness, Soil Sickness, or Legume Sickness, is very probably due to inhibiting factors such as the presence of pirate bacteria, truly parasitic or ineffective strains of nodule bacteria.

Field Inoculation of Leguminous Cover Plants

The above experiments have a very important bearing on the problem of inoculation of cover plants in the field. Dealing with *Centrosema pubescens*, it is found that several species of *Rhizobia* are capable of producing beneficial symbiosis. These several species have been isolated from *Centrosema* plants obtained from areas of different soil types and the probability is that these organisms are variants of the one species and have probably adapted themselves to their respective local environment. It will therefore be necessary to exercise considerable care in selecting the culture with which the new crop is to be inoculated. There will no doubt be a tendency to use mixed cultures of *Rhizobia*, in order to increase the chances of obtaining the correct one. This, however, is shown to be a risky procedure in view of the chance of inoculating into the soil organisms which, even if not true parasites, may inhibit the production of beneficial nodulation.

In other countries various proprietary preparations have been advertised and used for inoculation and improvement of leguminous crops with very mixed results. The tendency to-day is to disregard preparations containing mixed soil cultures of doubtful or even unknown specificity and to use only bacteriologically pure cultures of the organism specific to the particular crop it is desired to grow.

Laboratories have been set up by many agricultural colleges and research stations and by the leading seedsmen and plant breeders, in which cultures are obtained from leguminous plants and thoroughly tested to determine their specific nature. To-day, therefore, it is possible to obtain a pure agar culture of the particular strain of organism which has been found to give maximum benefit to the crop for which it is required, a very different thing from the pot of soil, taken from an area where that crop used to grow well, one would have received some quarter of a century ago.

Several methods are in vogue for the inoculation of soil or seed with bacteria. The more useful are as follows:—

(1) By transferring one or two tons of soil per acre from an area in which the cover plant is found to grow and nodulate well. This method would be ruled out in this country on account of cost.

(2) By inoculating the wetted seed to be sown with fine soil obtained from the roots of well-grown cover plants.

(3) By inoculating dry seed with a mud or paste made by adding a little water to the fine soil shaken from the roots of well-grown cover plant of the species desired.

(4) By rendering the seeds sticky with sugar, glue or casein solution, then dusting them with fine soil from the roots of the well-grown cover plant.

(5) By the application to the seed of suspensions of proprietary cultures of "nitrogen gathering" bacteria. There are no local preparations of this type, and if there were it is likely that they would fail as in other countries, owing to lack of knowledge as to their specific nature and uses.

(6) By the use of composite cultures consisting of several species of *Rhizobia* specific respectively to various legumes. These mixed cultures, as shown above, while possessing some advantages, certainly have some disadvantages and are not to be recommended.

(7) By crushed nodule cultures. Nodules from well-grown cover crops are collected and crushed in water to form a milky fluid which may then be applied to the

seed. This method has already given good results and deserves consideration.

(8) By inoculation of seed or soil with a water or milk suspension of tested pure cultures on agar media obtained from desirable forms of nodules of cover plants of the same species as that of the seed to be sown.

Application of Laboratory Results to Field Conditions

As long ago as 1928 the writer obtained many cultures of nodule bacteria from the cover-plant experiments set up on the Sungei Buloh forest soil in the early years of the present R.R.I. Experiment Station.

The experience gained in these early days has proved of great help in quickly producing fresh isolations from various cover plants, all of which are now being tested by the writer, in the Pathological Division of the Rubber Research Institute, for their specific properties and for their effect when cross-inoculated into other species of legumes.

The Soils Division of the Rubber Research Institute is laying down a number of field experiments on different soil types with a view to determining the value of inoculation in establishing and maintaining covers in rubber areas, thus carrying into the field the results obtained in the laboratory by the Pathological Division, close collaboration between the two divisions being a feature of the whole scheme.

The following is a brief outline of these experiments, for which Mr. Hamilton of the Soils Division is responsible: —

(1) *Centrosema pubescens* will be used as the test plant in the first instance.

(2) Site of plots to be in replanted areas and in mature rubber areas, under normal shade.

(3) The plots will be manured and the soil lightly forked over to about 3 in. depth.

(4) Some soil from the areas will be taken to the laboratories for critical culture tests.

(5) Various manurial treatments will be combined with the inoculation treatments.

(6) Good seed of *Centrosema pubescens* will be obtained and sterilized the day before sowing by immersion in hot water at 60°C. for twenty minutes.

(7) The seed will be inoculated by taking a water suspension of the growth of bacteria on a six- or seven-day-old agar slope culture of the organism to be tested. This suspension will be poured over the seed and allowed to dry for a few hours.

(8) Uninoculated control plots will also be kept for comparison.

Later other methods of inoculation of soil or seed will be attempted.

It will be noted that the hot water method of sterilization of the seed is to be adopted. This is because the use of chemical disinfectants may have an adverse or even fatal effect on the thin water culture of the organism which is subsequently to be applied, if all the disinfectant is not first removed with sterile water. Also the hot water method can easily be applied with safety on the average rubber estate in Malaya, and in addition this method will improve germination.

Possible Reasons for Failure of Leguminous Cover-Plants in Malaya

1. The species of leguminous plant may not be indigenous and may fail from inherent factors to adapt themselves to Malayan climate and soils conditions. Many of the known, good leguminous, forage crops prefer or require a long season's growth culminating in flowering

and seeding followed by withering of tops and a definite rest from growth, in cold or dry season.

In Malaya, growth with flowering and seeding is almost continuous throughout the year, affording little opportunity for a seasonal rest. However, most of the legumes now normally used as covers in rubber areas are able to do fairly well under Malayan climatic conditions if other conditions are favourable.

2. With the exception of coastal clay soils, most Malayan soils are inadequately supplied with phosphate for the satisfactory growth of legumes. Although Malayan soils are in general well supplied with potash, this also becomes a limiting factor in sandy areas and in old areas which have been badly eroded. It is possible also that calcium and magnesium may be inadequate for maximum growth, but this requires further investigation.

Aeration is another soil factor which may seriously interfere with the growth of legumes. Adequate soil aeration is necessary in order that the organisms can obtain the necessary nitrogen for assimilation. Aeration is only likely to become a limiting factor in clay soils, particularly badly-drained coastal clays. In this case drainage is the best remedy, although a certain amount of cultivation will also do good. The importance of aeration is proved in the laboratory by the fact that it is essential to blow in fresh air to the culture tubes either sand or nitrogen-free nutrient liquid, each day in order to obtain the formation of nodules and proper symbiotic activity.

3. *Shade.*—Failure of leguminous covers usually occurs about the third or fourth year of growth, culminating in their complete disappearance from the area at about the sixth or seventh year, except in a very few isolated places where such species as *Vigna* or *Centrosema* or *Pueraria* have lasted surprisingly well.

The failure may be due to the effect on the foliage of lines of rubber trees gradually closing in and blocking out the effective necessary light rays. If this is so there seems little hope of establishing leguminous covers in mature rubber areas, unless a species or variety of the legume can be produced which is tolerant to shade.

On the other hand, leguminous covers are known to fail after a few years in cover crop nurseries where no shade is to be found. It would seem therefore that the shade question is not of major importance. Failure of legumes under shade is usually coupled with unsuitable soil conditions. If these are made suitable, it is possible that covers will persist under dense shade, as indeed they do on many estates in Java and Sumatra and on some in Malaya.

4. *Seed.*—The failure of legumes may be due to degeneration of the self-sown seed, assuming the parent not to be a true perennial, to which the answer is: "Supply new imported", or it may be due to a disease of the type known in temperate climates as "Clover Sickness" or Legume sickness mentioned above.

5. *Diseases and Pests.*—Failure may be due to diseases of the legumes which have not yet received due attention. The extent and gravity of the *Nematode* (eelworm) pest of roots of legume cover plants is not generally appreciated. Yet an examination of the roots of failing leguminous cover plants almost invariably reveals the amazing ravages of this little-known microscopic pest, which is prevalent not only in Malaya but in other countries and is the subject of very strict official regulations regarding planting of legumes in most countries in temperate climates and many sub-tropical climates.

In the case of some of the more important forage legumes, agriculturists have produced species immune to nematode attack. This problem should receive special attention in Malaya if it is desired to establish low-growing or bush leguminous covers on the more friable soils commonly found in river flats and other inland districts of Malaya.

The chemical control of nematodes in soil is one of the great stumbling blocks in modern agriculture and the pests can at present be kept in check by two possible methods, viz.:—

(1) By growing only immune varieties of legumes.

(2) By alternation of legumes with other, non-susceptible crops. This means that as soon as the legume crop begins to fail owing to nematode attack of the roots, then that crop must be removed or destroyed and other crops substituted over a period of several years.

6. *Lack of Bacteria.*—It is possible that, as in some temperate countries, imported leguminous plants are unable to survive owing to lack of the requisite organisms in the soil for nodule production. As has already been explained, these nodule organisms work in symbiosis with the plant, deriving their organic food from the plant and in return supplying to the plant nitrogenous compounds which they have obtained by assimilation of nitrogen from the atmosphere of the soil. This can be remedied by inoculating the seed or soil as described above.

7. *Legume Sickness.*—It has been found that in Malaya, as in other countries, several varieties or even species of the nodule organisms of the family *Rhizobium* may exist and that one variety may be found in or be suitable to some districts or soil types and not to others. Similarly the organism commonly found in the nodules of one species of legume may be quite unsuitable for inoculation of other species, e.g. the organisms from nodules of *Pueraria* will not form nodules or support symbiotically the growth of *Centrosema* and vice versa. Some species may produce parasitic nodulation or may inhibit nodulation altogether.

Conclusions

During the past year or so there appears to have arisen a feeling in the planting world that natural covers were not going far enough in the scheme of regeneration of soil on rubber estates, and attention has again been turned to the possibility of establishing leguminous covers in old rubber areas. In this lecture I have tried to convey some idea of the biology of the legume plants and to indicate how this mutual beneficial growth can be used for the ultimate benefit of both crop and soil.

The specific character of the organism associated with the various species of leguminous plants in Malaya is stressed, and managers contemplating field or seed inoculation are advised to take great care to see that they are using the correct culture for the purpose in view and that the cleanest possible technique is used when handling such cultures.